FINAL PERFORMANCE REPORT
SOUTH CAROLINA STATE WILDLIFE GRANT PROJECT T-41-R
SOUTH CAROLINA DEPARTMENT OF NATURAL RESOURCES
OCTOBER 1, 2008—SEPTEMBER 30, 2016

Project Title: Conservation of water, shore and seabirds in South Carolina

Prepared by

Felicia Sanders
Wildlife Biologist
South Carolina Department of Natural Resources
220 Santee Gun Club Road, McClellanville, SC 29458

Christy Hand
Wildlife Biologist
South Carolina Department of Natural Resources
585 Donnelley Drive, Green Pond, SC 29446

Janet Thibault
Wildlife Biologist
South Carolina Department of Natural Resources
217 Fort Johnson Road, Charleston, SC 29422

Mary Catherine Martin
Wildlife Biologist
South Carolina Department of Natural Resources
305 Black Oak Road, Bonneau, SC 29431

GOAL

To maintain continuity in management, monitoring and surveying of waterbirds, seabirds and shorebirds; maintain and update the existing store of information on distribution, habitats needs, abundance and productivity; and make this information available to managers and planners.

PROJECT NARRATIVE

Need

Of the 65 seabird, shorebird, and wading bird species that utilize South Carolina's coastal habitats throughout the year, 47 are listed in the SC State Wildlife Action Plan (SWAP) as highest or high conservation concern, 3 are federally listed and 5 are state listed. The State of the Birds report for the U.S. (2009) reports that shorebirds are of highest conservation concern due to small and highly threatened global populations. Declines are attributed to human disturbance and dwindling food supplies. The coast of South Carolina is the most rapidly developing area of the state and the majority of South Carolina's seabirds, shorebirds and wading birds use this portion of the state.

Colonial nesting water birds are vulnerable because they concentrate into relatively few sites for nesting and a small number of sites can support a significant percentage of the total nesting population. Concentrated nesting results in the potential for nest failure and colony abandonment if good nesting conditions are not maintained. The combination of coastal development and recent droughts has resulted in large and significant declines in most heron and egret species. Colonies have become smaller and unstable and the total nesting population is much reduced. Many colonies have relocated from natural wetlands to manmade wetlands in response to drought. This has increased disturbance and resulted in conflicts with landowners.

Because of increased threats to coastal birds, it is necessary to continue management and monitoring seabirds, shorebirds and wading birds (populations and habitats) in South Carolina. Ongoing effort is needed to continue to work with partners to manage and protect priority species and their habitats. Data from nest counts and population surveys will be incorporated into a long term data base to allow the agency to make informed management decisions as well as contribute to regional and global knowledge of the species. SCDNR webpages about seabirds, shorebirds and wading birds in South Carolina will aid in public education and make information available to partners.

Objectives

1. Coordinate and implement monitoring and management activities for wading birds
    - Meet recovery plan monitoring requirements for wood storks by conducting aerial surveys.
    - Monitor distribution and relative size of wading bird colonies.
    - Provide management recommendations and guidance to public and private lands.
2. Coordinate and implement monitoring, conservation and management of seabirds and shorebirds
    - Post signs to reduce disturbance on public and private islands and monitor for evidence of violations on DNR properties. Provide technical assistance to island and beach owners on how to conserve nesting seabirds.
    - Annually conduct complete ground counts for all seabird species. Develop alternative methods to census seabirds, such as using aerial photography.
    - Provide technical assistance for roof management to facilitate good habitat for nesting birds (e.g., least terns). Check for nesting at these sites.
    - Coordinate surveys and management for shorebirds (resident and migratory).
    - Develop an outreach/educational component of the seabird/shorebird project
    - Apply pesticides where necessary to control avian ticks.

Accomplishments

Summary

During this project, SCDNR conducted annual surveys of nesting wading birds such as great egrets, snowy egrets, cattle egrets, great blue herons, tricolored herons, little blue herons, black-crowned night herons, white ibis, and glossy ibis. Wood stork nests were censused annually. Over 1,100 surveys were conducted (aerial and/or via canoe). Four aerial transect plots were established in an effort to develop a method of monitoring population trends of multiple wading

bird species. Five index colonies were established for the intensive monitoring of wood stork nesting success. Nearly 2,000 wood stork nesting attempts were monitored. Over 300 wood stork nestlings were banded. Data from surveys and nest monitoring were used to prioritize sites for habitat management actions such as herbicide treatments to reduce predation and tree plantings to increase nest site availability. Record high numbers of wood storks nesting in South Carolina during the past three years, and nesting success has been relatively high during 2011-2016. Survey data were provided to land use planners and landowners. Management recommendations and guidance were provided to public and private land managers. Information about the wading bird project and wading bird management opportunities was shared via a SCDNR website developed for the project, news releases, and articles in newspapers and the South Carolina Wildlife Magazine. SCDNR contributed to regional conservation planning by participating in annual Wood Stork Working Group Meetings and in professional conferences.

During this grant, population estimates for seabirds occurred annually by counting nests or adults at all major seabird colonies on the coast of South Carolina. Target species were brown pelicans, royal terns, sandwich terns, Forster's terns, common terns, least terns and black skimmers. Additionally least terns nesting on pebbled roofs were monitored and significant improvements were made to these manmade nesting sites with resulting increased fledge success. Techniques to improve accuracy of seabird nest counts and decrease disturbance to colonies were perfected. At large seabird colonies, nest estimates were obtained from digital aerial photographs taken from a plane or drone. The first statewide winter shorebird counts were organized in 2014 and 2015. Over 47,000 shorebirds were counted in the 2015 survey. The first statewide Wilson's plover, a state threatened shorebird, breeding pair survey resulted in an estimate for South Carolina of 376 pairs. The number of International Shorebird Surveys (ISS) increased to 21 sites covered during this grant. This increased effort to survey for shorebirds occurred because of workshops and trainings for partners and SCDNR staff. A SCDNR web page about seabirds and shorebirds was produced to include information about key species and ways that partners can participate in conservation efforts. This grant funded many research, monitoring and survey efforts not summarized in this report. These project resulted in 17 peer reviewed publications and reflect significant advancements in our understanding of seabirds and shorebirds in South Carolina.

Objective 1. Coordinate and implement monitoring and management activities for waterbirds

Activity:

a. Meet recovery plan monitoring requirements for wood storks by conducting aerial surveys.

   Wood Stork Nesting Effort Surveys
   The SCDNR Wading Bird Project surveyed all wood storks colonies that were known to be active during 2008 and 2011 – 2016 (Table 1, Figures 1 and 2). Aerial surveys were used to locate the nesting colonies. Stork nests were counted during ground surveys or, when ground surveys were not possible, from photographs taken during aerial surveys. Complete surveys were not conducted during 2009 and 2010 because staff was not hired to coordinate and conduct the surveys. Point-to-point flights were used to survey wading bird colonies of the coastal region and coastal plains where suitable stork nesting habitat was known to exist. Nineteen previously unknown stork colonies were identified and

surveyed during 2008-2016. Many were found during flights, but a few were reported by the public.

State Wildlife Grant T-41-R funded the salary for a biologist and technician to plan and conduct surveys, nest monitoring, and management activities. Flights were funded by a Coastal Program grant (USFWS Grant Agreement No. 40181AG128). Surveys were conducted from fixed-wing aircraft (Cessna 206, Cessna 210, and Vulcan Air P68) owned and operated by SCDNR Law Enforcement Division.

Wood Stork Colony Fate Surveys

During mid-June, additional point-to-point flights were used to determine if storks were successful at raising chicks or if the colonies had failed during the nesting season (Table 1). When necessary, additional flights were conducted during mid-July to determine the status of nesting attempts that were initiated during late spring. Colonies were considered to be successful if large stork chicks and/or recent fledglings were observed in the majority of the number of nests counted during the annual census.

During all years, storks successfully fledged chicks at the majority of their colonies. Wood storks typically nest in trees in flooded forests or on small islands surrounded by water. If there is adequate water, alligators below the nests deter predators such as raccoons from swimming to the nesting trees and eating stork eggs and/or chicks.

Mammalian predation is believed to be the primary cause of reproductive failure at unsuccessful colonies where storks nested in shrubs along the edges of ponds in residential communities. Other potential causes of colony failure for wood storks include inadequate or inaccessible food during the chick rearing period and disturbance. If adult storks are disturbed and leave their nests, crows and other predators have the opportunity to depredate eggs and small chicks. Even where predators are not a threat, disturbance can result in nest failure because eggs and small chicks are vulnerable to overheating when adults are not able to shade their nests.

Wood Stork Nest Monitoring

During 2011, SCDNR began monitoring a sub-set of the stork nests in index colonies to determine how successful the storks are at raising young in South Carolina. During 2012-2016, SCDNR staff, USFWS staff, and two trained volunteers monitored nests at seven colonies located between Savannah and Charleston. Two of the index colonies are on land managed by SCDNR (Donnelley Wildlife Management Area and Dungannon Plantation Heritage Preserve), and the other five colonies are on private land. Some years, additional colonies were also monitored.

At each colony, individual stork nests were mapped as they were initiated, and were monitored from a distance (using a spotting scope or binoculars) approximately once per week from the time that egg laying began until the chicks reached fledging age (mature enough to fly, which is about 7-8 weeks after hatching). The average number of chicks that survived to fledging age per nest was determined for each colony. A detailed protocol was used to standardize monitoring techniques (protocol is available by request).

During 2011-2016, a total of 1,949 stork nests were monitored in seven colonies, and an average of 1.8 chicks fledged per nest site (Tables 2 and 3). An average of 2.3 chicks fledged per successful nest site. The federal recovery goal for wood storks is an average of 1.5 fledglings per nest.

Wood Stork Banding

Beginning during 2013, SCDNR banded wood stork nestlings as part of a regional project. Over 300 storks were banded in South Carolina during 2013-2016. Two storks that were banded as nestlings during 2013 were seen nesting during 2016 in the colony where they were banded.

Conclusions from Stork Surveys and Monitoring

Overall, 2011 – 2016 were productive nesting seasons for wood storks in South Carolina. The three and five year averages of the number of stork nests counted in South Carolina were 2,503 and 2,277, respectively. This grant period was the first time that either of these averages have exceeded 2,000 nests per year since storks were first documented nesting in South Carolina during 1981. South Carolina stork colonies are playing an important role in the recovery of the species. The diverse and extensive wetlands in the coastal region of South Carolina provide more consistent prey throughout the nesting season compared to most of the Southeastern USA. Managed tidal impoundments provide concentrated prey as water levels are lowered, and tidal creeks concentrate prey during low tides due to the high tidal amplitude along the coast.

Much of South Carolina experienced drought conditions during 2011 and 2012, but the 2013 – 2015 nesting seasons were very wet and were favorable for nesting storks. The index colony located farthest from the coast had low productivity during 2012 (0.7 fledglings per nest site) and seemed to be more affected by drought conditions than colonies in more coastal areas. Starting with the historic flooding event in October of 2015, the lowcountry was very wet during the fall and winter of 2015/2016. Wetlands gradually dried during the spring but were re-flooded during late-May when many storks were raising young chicks. Higher than average mortality of young chicks was observed in inland rookeries during this period. Chicks that were over 4 weeks old were able to be left unattended while both parents foraged, so they were less affected by the shortage of accessible prey.

Table 1. Numbers of wood stork nests counted in South Carolina during 2008, 2011, 2012, 2013, 2014, 2015, and 2016. Colonies are listed in the order that they first were known to be active. Colonies that have not been active since the 1990s were not surveyed every year. Aerial surveys were used to locate colonies and to determine the status of colonies. Nests were counted from aerial photographs or colonies were also surveyed from the ground so nests could be counted more accurately.

Colony Number	County	Number of Nests and Fate of Majority of Nests						
		2008*	2011	2012	2013	2014	2015	2016
Colony 01	Colleton	0	0	No Survey	No Survey	No Survey	No Survey	No Survey
Colony 02	Colleton	1	No Survey	No Survey	No Survey	No Survey	No Survey	No Survey
Colony 03	Hampton	2	106, Success	0	195, Success	267, Success	268, Success	283, Success
Colony 04	Colleton	3	0	0	0	0	0	0
Colony 05	Colleton	4	0	No Survey	No Survey	No Survey	No Survey	No Survey
Colony 06	Colleton	5	391, Success	390 Success	368, Success	442, Success	368, Success	314, Success
Colony 07	Charleston	6	173, Success	168, Success	228, Success	263, Success	282, Success	203, Success
Colony 08	Charleston	237	169, Success	157, Success	61, Success	226, Success	229, Success	269, Success
Colony 09	Hampton	0	0	No Survey	No Survey	0	No Survey	No Survey
Colony 10	Bamberg	0	0	No Survey	No Survey	30 Success	49, Success	85, Success
Colony 11	Jasper	160	5, Fail	0	0	0	0	0
Colony 12	Georgetown	0	0	No Survey	No Survey	No survey	No survey	No Survey
Colony 13	Horry	44	154, Success	64, Fail	171, Success	179, Success	118, Success	152, Success
Colony 14	Berkeley	0	No Survey	No Survey	No Survey	No Survey	No Survey	No Survey
Colony 15	Colleton	0	0	No Survey	No Survey	No Survey	No Survey	No Survey
Colony 16	Charleston	87	84, Fail	0	12, Fail	12, Fail	0	0
Colony 17	Horry	0	2, Success	4, Success	0	0	0	0
Colony 18	Charleston	0	0	No Survey	No Survey	No Survey	No Survey	No Survey
Colony 19	Georgetown	0	10, Success	6, Fail	67, Success	83, Success	129, Success	14, Fail
Colony 20	Colleton	202	248, Success	246, Success	205, Success	315, Success	207, Success	177, Success
Colony 21	Georgetown	125	151, Success	219, Success	160 Success	164, Success	181, Success	167, Success
Colony 22	Beaufort	12	0	0	0	0	0	0
Colony 23	Charleston	101	188, Success	167, Success	150 Success	180 Success	168, Success	229, Success
Colony 24	Beaufort	35	No Survey	47, Success	44, Success	0	13, Success	28, Success
Colony 25	Colleton	64	107, Success	78, Success	107, Success	124, Success	169, Success	139, Success
Colony 26	Beaufort	7	5, Fail	9, Success	12, Success	18, Success	29, Success	36, Success
Colony 27	Horry	0	47, Success	0	0	0	0	0
Colony 28	Charleston	7	0	0	1, Fail	14, Success	52, Success	87, Success
Colony 29	Beaufort	2	44, Fail	24, Fail	3, Fail	8, Fail	9, Success	7, Fail
Colony 30	Jasper	No Survey	28, Unknown	109, Success	94, Success	73, Success	52, Success	63, Success
Colony 31	Beaufort	No Survey	11, Fail	0	0	0	0	0
Colony 32	Beaufort	No Survey	19, Fail	0	0	0	0	0
Colony 33	Horry	No Survey	49, Success	45, Success	85, Fail	0	0	0
Colony 34	Beaufort	No Survey	13, Success	55, Success	56, Success	54, Success	63, Success	48, Success
Colony 35	Charleston	No Survey	24, Success	15, Success	10 Fail	0	0	0
Colony 36	Williamsburg	No Survey	3, Fail	0	0	0	No Survey	No Survey
Colony 37	Jasper	No Survey	0	11, Fail	0	0	0	0

Colony Number	County	Number of Nests and Fate of Majority of Nests						
		2008*	2011	2012	2013	2014	2015	2016
Colony 38	Beaufort	No Survey	0	13, Fail	0	4, Success	2, Fail	15, Success
Colony 39	Beaufort	No Survey	No Survey	No Survey	20 Success	26, Success	75, Success	91, Success
Colony 40	Berkeley	No Survey	No Survey	No Survey	1, Success	0	0	0
Colony 41	Beaufort	No Survey	No Survey	No Survey	0	4, Fail	0	0
Colony 42	Beaufort	No Survey	No Survey	No Survey	0	11, Success	19, Success	15, Success
Colony 43	Beaufort	No Survey	No Survey	No Survey	No Survey	3, Fail	2, Success	0
Colony 44	Beaufort	No Survey	0	0	0	1, Fail	0	0
Colony 45	Beaufort	No Survey	No Survey	No Survey	No Survey	0	12, Fail	0
Colony 46	Beaufort	No Survey	No Survey	No Survey	No Survey	No Survey	No Survey	5, Fail
Colony 47	Horry	No Survey	No Survey	No Survey	No Survey	No Survey	No Survey	49, Success
Colony 48	Horry	No Survey	No Survey	No Survey	No Survey	No Survey	No Survey	27, Success
Colony 49	Berkeley	No Survey	No Survey	No Survey	No Survey	No Survey	No Survey	9, Success
Number of Nests		1839	2031	1827	2050	2501	2496	2512
Number of Active Colonies		16	24	19	21	23	22	24
Colony Fates								
Successful		NA	15	14	16	18	20	21
Failed		NA	7	5	5	5	2	3
Unknown		NA	2	0	0	0	0	0

* Colony fates not available for 2008. Nest count data are not available for most colonies during 2009 and 2010.

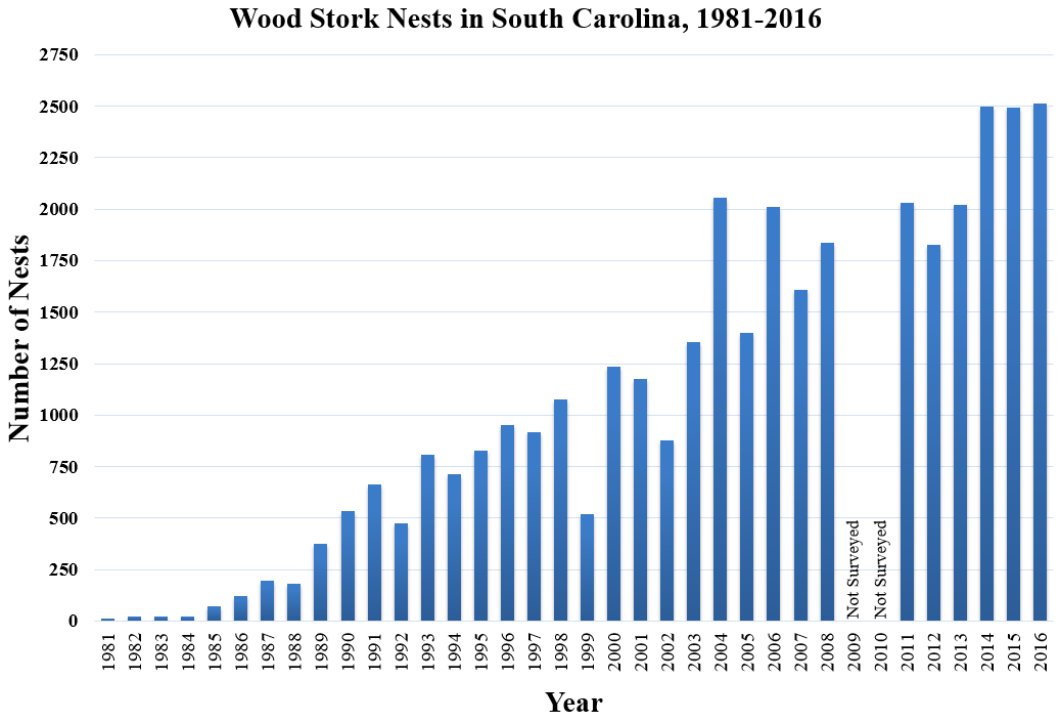

Figure 1. Number of wood stork nests counted in South Carolina during annual censuses from 1981 – 2016.

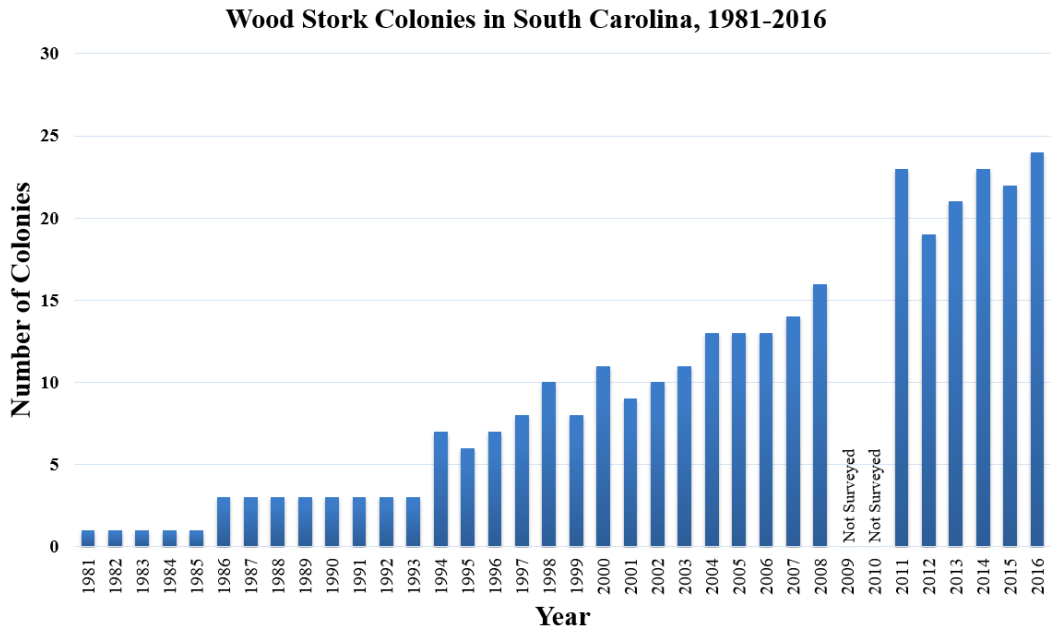

Figure 2. Number of colonies in which wood storks nested in South Carolina from 1981 – 2016.

Table 2. Comparison of annual wood stork nest monitoring data collected by South Carolina Department of Natural Resources staff, US Fish & Wildlife Service staff, and volunteers during 2011-2016.

Year	2011	2012	2013	2014	2015	2016	All Years
Number of Monitored Nest Sites	81	311	427	396	412	322	1949
Average Fledglings per Nest Site	1.6	1.1	1.4	2.2	2.3	1.7	1.8
Average Fledgings per Successful Nest Site	2.1	1.9	2.0	2.6	2.5	2.3	2.3
0 Fledglings	18	122	144	49	48	88	469 (24%)
1 Fledgling	11	53	55	28	26	42	215 (11%)
2 Fledglings	38	107	163	126	144	98	676 (35%)
3 Fledglings	14	28	59	163	168	73	505 (26%)
4 Fledglings	0	1	6	30	29	21	87 (4%)
% Successful*	77%	61%	66%	88%	89%	74%	76%

* Number of successful nest sites divided by the total number of nest sites that were monitored. Successful is defined as producing at least one fledgling. A chick was considered to be a fledgling if it survived to at least 7 weeks of age.

Table 3. Summary of wood stork nest monitoring data collected by South Carolina Department of Natural Resources staff, US Fish & Wildlife Service staff, and volunteers during 2016. Individual nests were monitored in 7 of the 24 colonies where storks nested during 2016. Detailed summaries for 2011-2015 are included in interim reports.

Colony Number and County	**Colony 6 Colleton**	**Colony 7 Charleston**	**Colony 20 Colleton**	**Colony 23 Charleston**	**Colony 25 Colleton**	**Colony 29 Beaufort**	**Colony 34 Beaufort**	**All Monitored Colonies**
Ownership	**Private**	**Dungannon HP**	**Private**	**Private**	**Donnelley WMA**	**Private**	**Private**	
Total Number of Stork Nests in Colony*	314	203	177	229	139	7	48	1117
Number of Monitored Nest Sites	138	45	43	43	12	7	34	322
Average Fledglings per Nest Site	1.2	2.3	2.1	2.2	2.3	0.0	2.0	1.7
Average Fledgings per Successful Nest Site	1.9	2.7	2.6	2.3	2.5	0.0	2.5	2.3
0 Fledglings	55	7	8	3	1	7	7	88
1 Fledgling	27	5	4	4	1	0	1	42
2 Fledglings	39	10	12	22	4	0	11	98
3 Fledglings	12	15	14	11	6	0	15	73
4 Fledglings	5	8	5	3	0	0	0	21
% Successful**	60%	87%	81%	93%	94%	0%	79%	74%

*Total number of nests counted in the colony during the annual colony survey.

** Number of successful nest sites divided by the total number of nest sites that were monitored. Successful is defined as producing at least one fledgling. A chick was considered to be a fledgling if it survived to at least 7 weeks of age.

b. Monitor distribution and relative size of wading bird colonies.

Aerial surveys and ground counts of nests in known wading bird colonies and in aerial transect survey plots were used to monitor the distribution and relative size of wading bird colonies during 2011- 2016. All species of wading birds were included in the surveys. The number of roseate spoonbills in South Carolina during the post-breeding season appears to be increasing; however, nesting has not yet been confirmed in the state. Many of the spoonbills seen in South Carolina are immature individuals. No reddish egret nests were found during the 2011-2016 surveys. Yellow-crowned night herons and green herons often nest in small inconspicuous colonies and were rarely located during surveys.

Aerial Surveys of Known Colonies

Point-to-point aerial surveys were used to determine the status of existing colonies. We focused our efforts on the areas that were most likely to have wood stork colonies. The flights were timed to coincide with peak nesting for wood storks and great egrets in the coastal region. Nest numbers were estimated and all species seen in each colony were recorded during the aerial surveys. Aerial photographs were taken of all active colonies.

Aerial Transect Surveys Plots

Aerial surveys are valuable for determining the distribution of active colonies; however, the nests of most species of wading birds cannot be accurately counted from a plane. The historic aerial survey data for species other than wood storks are not accurate enough to determine population trends. State-wide ground surveys potentially could be more accurate, but are too costly and disruptive to nesting wading birds to be conducted on a frequent enough basis to produce reliable trend data. With recent improvements to digital SLR cameras, aerial photographs taken during survey flights can often be used to identify species and estimate the number of nests in most colonies.

After consulting with Dr. Peter Frederick, University of Florida, and other wading bird experts, we established four aerial transect plots (Figure 3) to improve our ability to monitor population trends. Each transect plot includes 18 transect lines that are 2.5 km apart. Plots were placed in areas with high concentrations of current and historic wading bird colonies. The two coastal plots are perpendicular to the coast to allow us to survey a gradient of coastal habitat. Each plot is approximately 70 km long and 35 km wide. Areas that have access restrictions (closed airspaces) or open water were not included in the plots, so some transect lines are shorter than the plot boundaries. Surveys were conducted from and altitude of approximately 700 ft above ground level (600-800 ft AGL).

Transect flights were conducted during 2012 (North and South Coastal Plots), 2013 (Inland and Central Plots) and 2016 (all plots, Figure 4). During the transect flights, two observers looked for wading bird colonies from the rear seats of the airplane. The pilot and the navigator/photographer in the front seats also looked for colonies when possible. When active colonies were located, coordinates were recorded and aerial photographs were taken. The planes occasionally were forced to deviate from the planned routes due to airspace

restrictions (i.e. active military operations) and thunderstorms. Aerial photographs were taken at all active colonies. The goal during surveys was to locate all active colonies and to accurately count nests of all focal species in within each plot. Due to airspace restrictions and the logistical challenges of accurately surveying wading birds it is likely that some active colonies may not have been found during the surveys. Follow up surveys from the ground/canoe were conducted at many colonies within the plots during 2012 and 2013; however, most colonies were only surveyed from the air/aerial photographs during 2016 due to time constraints.

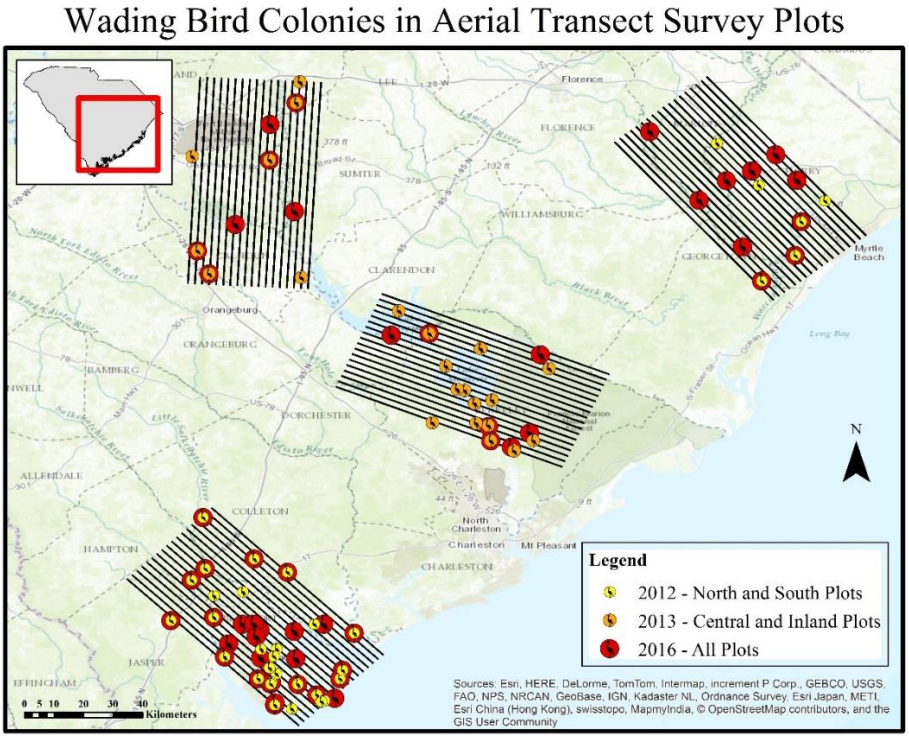

Figure 3. Active wading bird colonies located in aerial transect plots during 2012, 2013 and 2016 surveys. Each of the four survey plots is approximately 70 km long, 35 km wide and includes 18 transect lines spaced 2.5 km apart.

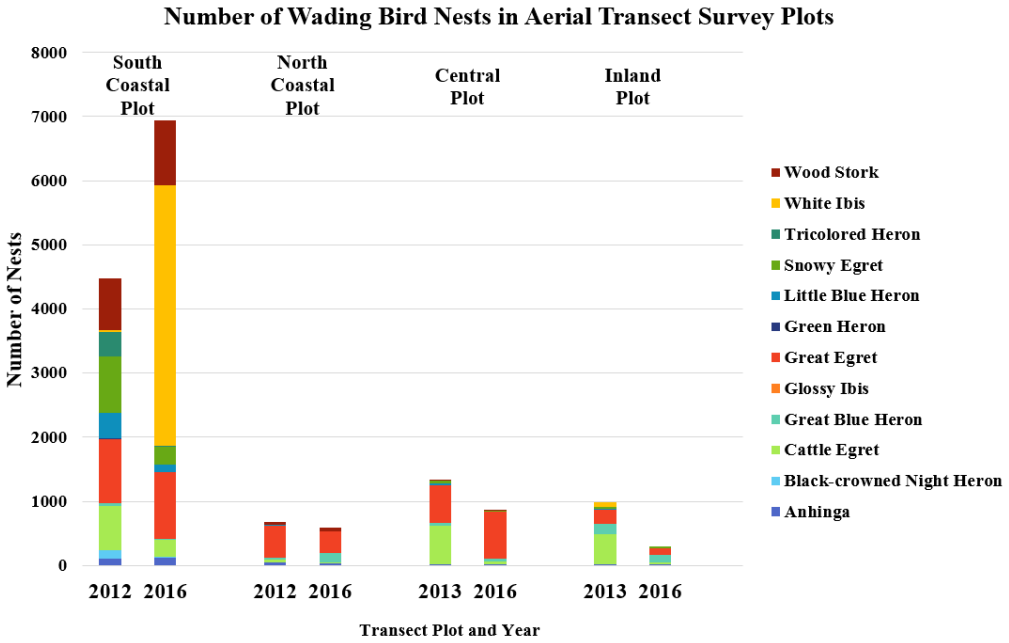

Figure 4. Wading bird abundance and species composition by year in aerial transect survey plots.

Table 4. Number of nests counted per species in colonies surveyed in transect plots during 2012/2013 and 2016. Each of the four survey plots is approximately 70 km long, 35 km wide, and includes18 transect lines spaced 2.5 km apart. Due to airspace restrictions and the logistical challenges of accurately surveying wading birds, count data are estimates and some active colonies may not have been found during the survey.

Transect Plot, Year, and Colony Code	Number of Nests per Species												Total Nests per Year and Colony
	Anhinga	Black-crowned Night Heron	Cattle Egret	Great Blue Heron	Glossy Ibis	Great Egret	Green Heron	Little Blue Heron	Snowy Egret	Tricolored Heron	White Ibis	Wood Stork	
North Coastal Plot													
2012	**45**	**3**	**49**	**28**	**0**	**500**	**1**	**3**	**0**	**0**	**0**	**51**	**680**
22025	26			4		7						6	43
26003	8	3	49	1		425	1	3					490
26007	1			3		23						45	72
26010	10			19		45							74
26011				1									1
2016	**33**	**0**	**9**	**147**	**0**	**340**	**0**	**3**	**0**	**0**	**0**	**63**	**595**
21200	7		1	44		4							56
22025				2		1						14	17
22206	15			19		27							61
26003	8		8	3		299		3					321
26009				30									30
26013	3			1		9						49	62
26014				22									22
26015				8									8
26016				5									5
34202				13									13

Transect Plot, Year, and Colony Code	Number of Nests per Species												Total Nests per Year and Colony
	Anhinga	Black-crowned Night Heron	Cattle Egret	Great Blue Heron	Glossy Ibis	Great Egret	Green Heron	Little Blue Heron	Snowy Egret	Tricolored Heron	White Ibis	Wood Stork	
South Coastal Plot													
2012	**105**	**136**	**687**	**47**	**0**	**992**	**16**	**397**	**874**	**390**	**32**	**794**	**4470**
07006				7		7							14
07036				11								9	20
07037						65		5					70
07048		26	46			170	6	81	192	135			656
07057	0	16	5			45		2	35	3		47	153
07067						2							2
07071						3			3				6
07095	2	5	3			47		4	59	13			133
07200				8									8
07202	1	1				14	1		11				28
07304						2	1	1					4
07311	10	13	4	7		237			65				336
07315						5							5
07316		2				9							11
07317				1		6	8						15
07322						8						13	21
07325	1					29			2				32
07336	7	10	185			10		48	124	63			447
07337		39	24			40			17				120
07340		3				21			3				27
15018	33					95						390	518
15030						20							20
15031	14		149			117		59				246	585
15032	31	4	65			24		122	326	173	32	78	855

Transect Plot, Year, and Colony Code	Number of Nests per Species												Total Nests per Year and Colony
	Anhinga	Black-crowned Night Heron	Cattle Egret	Great Blue Heron	Glossy Ibis	Great Egret	Green Heron	Little Blue Heron	Snowy Egret	Tricolored Heron	White Ibis	Wood Stork	
25001						4							4
25005	2	14	191	1		3		75					286
27203	4			8		1						11	24
07207		3	15			3			23	3			47
15002				4									4
07334						5			14				19
2016	**125**	**7**	**261**	**18**	**6**	**1039**	**2**	**122**	**265**	**20**	**4060**	**1009**	**6934**
07036	1		1	12		76			37			36	163
07048						80			5				85
07057						19						25	44
07086			5			100			5				110
07090						15							15
07095	3					12							15
07301						18			4				22
07311						125							125
07322				2		3						15	20
07324						11							11
07325						12			3			15	30
07337		2	40		6	55		7	8	10			128
07342												5	5
07356		4	9			22			13				48
07364	2					5							7
07369						25			4				29
07370			3			5		15	87				110
07371						15			3				18
07372						1			23				24

Transect Plot, Year, and Colony Code	Number of Nests per Species												Total Nests per Year and Colony
	Anhinga	Black-crowned Night Heron	Cattle Egret	Great Blue Heron	Glossy Ibis	Great Egret	Green Heron	Little Blue Heron	Snowy Egret	Tricolored Heron	White Ibis	Wood Stork	
15018	52			3		85						314	454
15030	2		1			95			4				102
15031	16		157	1		172	1	34				177	558
15032	39	1	30			28	1	30	20	10		139	298
15035	3					3			19				25
25001	2		15			57			30			283	387
25005	1							36			4060		4097
27203	4												4

Transect Plot, Year, and Colony Code	Number of Nests per Species												Total Nests per Year and Colony
	Anhinga	Black-crowned Night Heron	Cattle Egret	Great Blue Heron	Glossy Ibis	Great Egret	Green Heron	Little Blue Heron	Snowy Egret	Tricolored Heron	White Ibis	Wood Stork	
Central Plot													
2013	**26**	**0**	**589**	**42**	**0**	**587**	**0**	**42**	**38**	**3**	**0**	**1**	**1328**
08002	6					467							473
08006	1			14		13							28
08015			7	1		13							21
08208	4			8		10						1	23
08206			34					12	5				51
08205						8							8
08051			11			19			7				37
08032													0
08207	3			9		16							28
08209				4		2							6
08210	3		108			5		9					125
08211													0
08212				5									5
08213													0
08214													0
14009	9		429	1		34		21	26	3			523
2016	**23**	**0**	**39**	**47**	**0**	**732**	**0**	**3**	**9**	**0**	**0**	**9**	**862**
08002						635							635
08003	11												11
08006	6		38	4		32			3				83
08015	6		1					3	6				16
08217				1		2						9	12
08218						63							63
38003				42									42

Transect Plot, Year, and Colony Code	Number of Nests per Species												Total Nests per Year and Colony
	Anhinga	Black-crowned Night Heron	Cattle Egret	Great Blue Heron	Glossy Ibis	Great Egret	Green Heron	Little Blue Heron	Snowy Egret	Tricolored Heron	White Ibis	Wood Stork	
Inland Plot													
2013	**23**	**0**	**466**	**166**	**0**	**221**	**0**	**15**	**24**	**0**	**70**	**0**	**985**
09005				2									2
28001	23		466	148		211		15	24		70		957
38013				5									5
40002				4		10							14
40005				1									1
28002				6									6
2016	**23**	**0**	**19**	**128**	**0**	**95**	**0**	**0**	**31**	**0**	**0**	**0**	**296**
09005				2									2
28001				40									40
38013				7									7
40002	11		19	3		78			31				142
40004	12			39		11							62
40007				4									4
43011				33		6							39

c. Recommend enhancement activities on SCDNR owned colony sites (e.g., water level).

SCDNR owns two properties with consistently active wood stork rookeries: Dungannon Plantation Heritage Preserve (Dungannon HP) and Donnelley Wildlife Management Area (Donnelley WMA). The wading bird biologist who was hired through this grant worked closely with the SCDNR biologists managing both properties and with the SCDNR aquatic nuisance species program staff to manage nesting habitat.

Following the recommendation of the wading bird biologist, in 2011 SCDNR began to annually close public access to the boardwalk that extends into the wood stork colony at Dungannon HP during the nesting season to protect wood storks from disturbance by humans and leashed dogs. During 2011-2016, wood storks successfully nested directly above the boardwalk, where there was less aquatic vegetation.

Herbicide treatments to control consolidated mats of floating vegetation that threaten the productivity of storks nesting in the colony were conducted at Dungannon HP and Donnelley WMA. Herbicide treatments in the rookery at Donnelley WMA were initiated during 2014 and continued during 2015 and 2016. At least two treatments were also completed each year at Dungannon HP between 2012 and 2015. The property was severely impacted by the October 2015 flooding event and hurricane Matthew during October 2016, so herbicide treatments could not be conducted. Repairs to the property are scheduled to be completed prior to the 2017 breeding season.

After we initiated herbicide treatments at Dungannon HP, the number of stork nests increased to over 200 each year from 2012-2016. The number of stork nests at Donnelley WMA also increased during the past few years.

d. Provide management recommendations and guidance to public and private lands.

SCDNR attended and participated in the annual Wood Stork Working Group meetings in Jacksonville and Vero Beach, Florida. South Carolina nesting data and an overview of the current management projects were presented to the group of researchers who make decisions about future priorities to promote the recovery of the species.

During 2014, DNR worked with the ACE Basin National Estuarine Research Reserve and other partners to organize and facilitate a workshop titled “Wading Bird Rookery Management: A seminar for community decision-makers who manage lands with rookeries or rookery habitat”. The goal of the workshop was to provide information about best management practices and regulations to managers of rookeries in residential communities in South Carolina. DNR gave a presentation about wading birds and their habitat requirements in South Carolina and enlisted federal and county officials to present about regulations. The workshop also included a field trip with experts who have experience creating and managing ponds for wading birds.

SCDNR worked with property owners who have significant stork colonies on their property to apply for a Coastal Program Grant to share the cost of herbicide treatments.

With the technical assistance and expertise of SCDNR and USFWS staff, treatments have been conducted at two rookeries on private land since 2012. A third rookery was added to the project during 2014. The project will continue until the spring of 2017. Details are available in a separate interim report for the project. (USFWS Cooperative Agreement No. F12AC01593.)

When the peak numbers of stork chicks were fledging (late June - July), private and public property managers who manage impounded wetlands in coastal South Carolina were contacted *via* email. An update on the status of the stork nesting season and information about managing foraging habitat for storks was provided to encourage management that would benefit young storks as they fledged from their nests. Water level management in impoundments used as foraging areas was discussed with SCDNR property managers, and impoundments at Bear Island WMA and Donnelley WMA were managed to benefit wading birds as well as waterfowl.

SCDNR maintains an ArcMap geodatabase of wading bird colony locations in South Carolina (Figure 5) that is used by land managers, permit reviewers, power companies, and other organizations to plan projects. The map is updated annually. These data are available upon request to organizations or individuals involved in making land management decisions. Colony locations are not available to the general public due to concerns about the privacy of the property owners and potential disturbance to the birds.

During 2008-2016, SCDNR was contacted by city, county, state, and federal employees, as well as private companies and contractors, who requested information about wading bird colony locations and statuses. This grant allowed SCDNR to collect data about wading birds and to provide it to a variety of organizations. Detailed information about colony boundaries is provided to organizations working near specific stork colonies to ensure compliance with the Endangered Species Act. Individuals who need access to wading bird colony data are encouraged to contact the wading bird biologist directly for assistance with their projects.

SCDNR developed and maintains a webpage for the Wading Bird Program (Figure 6). The webpage includes information about species and statuses, an overview of SCDNR's projects, guidance about viewing wading birds, and management recommendations for nesting and foraging areas. Private land managers are encouraged to contact SCDNR for additional guidance. Additionally, the majority of the owners and managers who have wood storks nesting on their properties receive letters in the fall with information about the survey results and contact information for the SCDNR biologist in case they would like management guidance. The biologist responded to various inquiries from the public about wading bird ecology throughout the year.

SCDNR periodically shared information about the wading bird project via news releases. The news releases were regularly picked up by South Carolina newspapers. Annual summaries about the status and success of wood storks nesting in South Carolina are available on the website. The South Carolina Wildlife Magazine featured the wading bird project in several articles and raised awareness of wading bird conservation efforts.

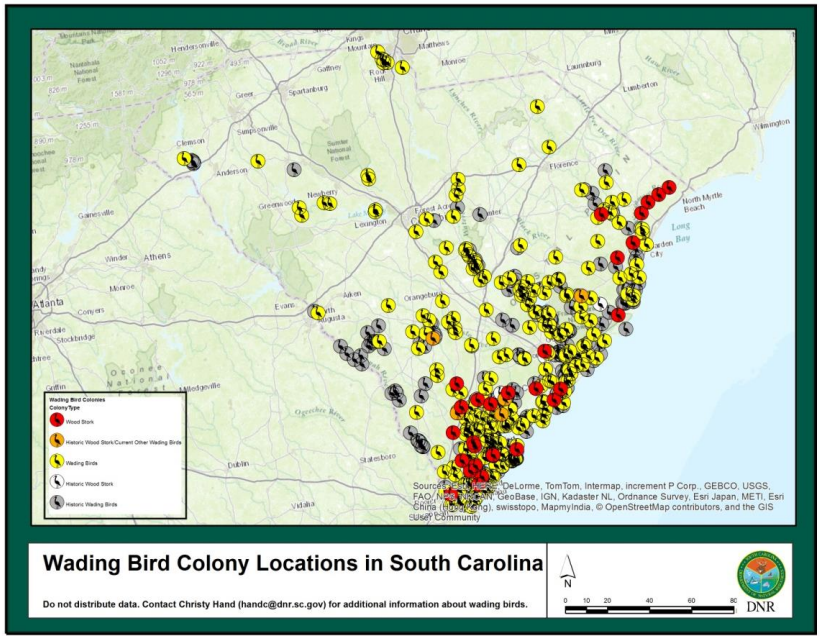

Figure 5. PDF of interactive ArcGIS layer package created by SCDNR for use by land managers and planners.

Figure 6. Screenshot of SCDNR Wading Bird webpage.

Significant deviations: None

Objective 2. Coordinate and implement monitoring and management activities of shorebirds and seabirds

Activity:

a. Post signs to reduce disturbance on public and private islands and monitor for evidence of violations on SCDNR properties. Provide technical assistance to island and beach owners on how to conserve nesting seabirds.

   Each year coordinated with private, federal, state, and county owned beach managers to close part of the beach for nesting seabirds and shorebirds. This involved 2-10 site visits at each property depending on the partnership with the land manager. Sites visits included meeting with managers to discuss importance of nest protection and monitoring; visits to place, maintain and remove signs; and nest monitoring. Additionally, educational signs were placed at boat ramps and on some beach entrances. We placed closure signs at nesting sites on 30 beaches and at 2 beaches during the winter to protect roosting migratory shorebirds (Table 5, Figure 7).

Table 5. Sites in South Carolina (N = 30) and property owner (or management authority), where signs were placed to protect beach nesting seabirds and shorebirds and migratory shorebirds from human disturbance.

SITE	OWNERSHIP
Cape Island	Cape Romain NWR
Lighthouse Island	Cape Romain NWR
Marsh Island	Cape Romain NWR
White Banks	Cape Romain NWR
Folly Beach	Charleston County Park
Kiawah	Charleston county park
Bosun's Point	North Inlet/Winyah Bay NERRS
Botany Island	Private
Castle Pinckney	Private
Dewees	Private
Harbor	Private
Hobcaw	Private
Seabrook	Private
Botany Bay Plantation	SCDNR Heritage Preserve
Capers Island	SCDNR Heritage Preserve
North Island	SCDNR Heritage Preserve
Otter/Pine Islands	SCDNR Heritage Preserve
Sand Island	SCDNR Heritage Preserve
South Island	SCDNR Heritage Preserve
Bird Key	SCDNR Heritage Preserve
Crab bank	SCDNR Heritage Preserve
Deveaux bank	SCDNR Heritage Preserve
North Santee Bar	SCDNR Heritage Preserve
Tomkins Island	SCDNR Heritage Preserve
Cedar Island	SCDNR Wildlife Management Area
Murphy Island	SCDNR Wildlife Management Area
Edisto	State Park
Hunting	State Park
Morris Island	Trust for Public Lands

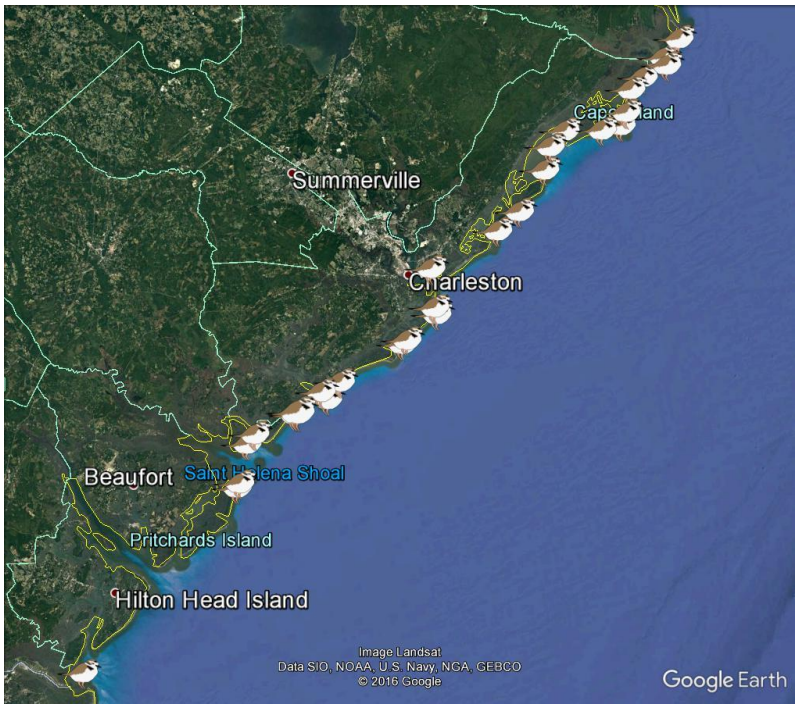

Figure 7. Locations of 30 sites (indicated by plover icons) where signs were placed to indicate beach closures. Closures help minimize human disturbance to beach-nesting birds and migratory shorebirds.

b. Annually conduct complete counts for all nesting seabirds in South Carolina. Develop alternative methods to census seabirds, such as using aerial photography.

To determine the abundance and distribution of nesting populations of seabirds in South Carolina, all active seabird colonies including black skimmer, brown pelican, common tern, Forster's tern, gull-billed tern, least tern, sandwich tern and royal tern were surveyed over the study period.

Ground Counts
Nests were counted on the ground at 12-21 sites (when active) and occurred during the peak incubation period of each species. Since these species nest directly on the ground in South Carolina and many colonies are comprised of hundreds to thousands of nesting pairs, counts were conducted by staff and volunteers. Ground counts consisted of staff and volunteers slowly walking transects through the colonies and tallying nests of each species.

The majority of seabird nests were censused by ground counts, however, in areas where ground counts were not possible, staff used binoculars or spotting scopes to count the number of adults sitting in incubation postures as a proxy for nest counts.
Ground counts can be somewhat disruptive especially to larger nesting seabirds such as brown pelicans that often dislodge eggs from nests or become tangled in dense vegetation when flushing from the nest. To reduce the amount of disturbance to brown pelicans and

to obtain more accurate counts, aerial photographic surveys of brown pelican colonies began in 2013.

Aerial Photographic Counts

SCDNR began conducting aerial photographic surveys of pelican colonies in 2013. Flights occur annually and are conducted by SCDNR Law Enforcement pilots in a twin engine fixed-wing Partenavia aircraft. Two SCDNR biologists accompany the pilot: one to help direct the pilot over pelican colonies and the other to take photographs of the colonies through Bombay doors in the aircraft.

The first aerial survey was conducted in 2013 of Deveaux Bank and has since expanded to several islands where brown pelicans nest in South Carolina. Flights are conducted in late May. Survey altitude is primarily 1000 ft. – 700 ft. and the aircraft often makes several passes over the colonies to ensure complete photographic coverage. Photographs are taken with a Cannon 50 D digital SLR camera. Counts from digital images are made using *Image J*, an image processing program which allows the user to tag items (pelican nests) for automatic count tallying (Figure 8).

Figure 8. *Image J*. processing software used to tally brown pelican nests from aerial photographs of Deveaux Bank, May 2014.

Unmanned Aerial Vehicle Pilot Study

In 2015, a pilot study to determine if Unmanned Aerial Vehicles (UAVs or Drones) are a suitable tool for surveying colonial seabirds and wading in South Carolina occurred. UAVs have the potential to capture superior aerial imagery compared to photographs taken from fixed-wing manned aircraft and may be able to collect data with less disturbance to the birds than ground counts. To begin to evaluate the response of nesting seabirds and wading birds to UAVs and the quality of aerial imagery that could be collected, SCDNR biologists worked with the company UASFocus, LLC to conduct an

UAV trial on a barrier island where several species of waterbirds were nesting. Throughout the trial, SCDNR biologists used spotting scopes to observe the behavior of pelicans, and terns, and were prepared to increase the distance of the UAV from the birds immediately if any indications of disturbance were observed (example: if the birds were looking at the UAV). To minimize disturbance, we followed recommendations from previous studies such as maintaining a consistent altitude while over the colony. During the trial, the UAV flew in a grid pattern while taking photographs. Throughout the trial, we did not observe any signs that the nesting birds were disturbed. No birds flushed from the colony or attempted to attack/approach the UAV.

The photographs collected by the UAV were mosaicked and georeferenced in GIS (Figure 9). Although the imagery was adequate enough to identify pelican nests, the clarity and resolution of the photographs was not adequate enough to consistently identify smaller nesting seabirds and distinguish between wading bird species. If UAVs are to be considered in the future, higher resolution cameras will be necessary to count nesting seabirds and wadingbirds from photographs.

The locations of the largest colonies are displayed in Figure 10 and number of nests counted or estimated by year are reported in Figures 11-15.

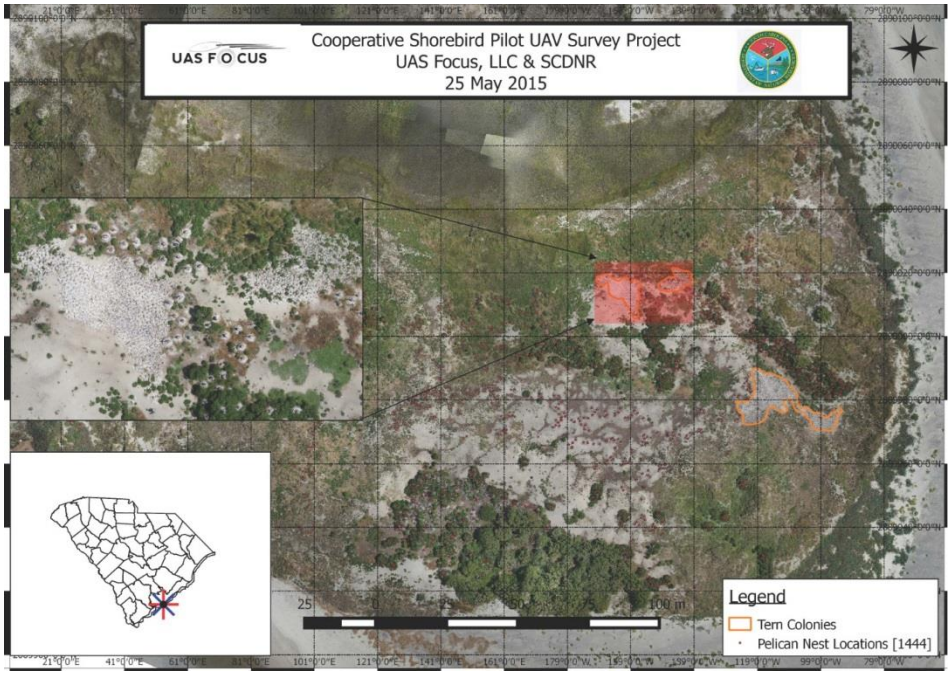

Figure 9. Georeferenced imagery collected during UAV trial. Egrets, herons, ibis, terns, pelicans, and gulls were nesting on this island during the trial, May 2015. (Provided by Greg Lynch, UAS Focus, LLC.)

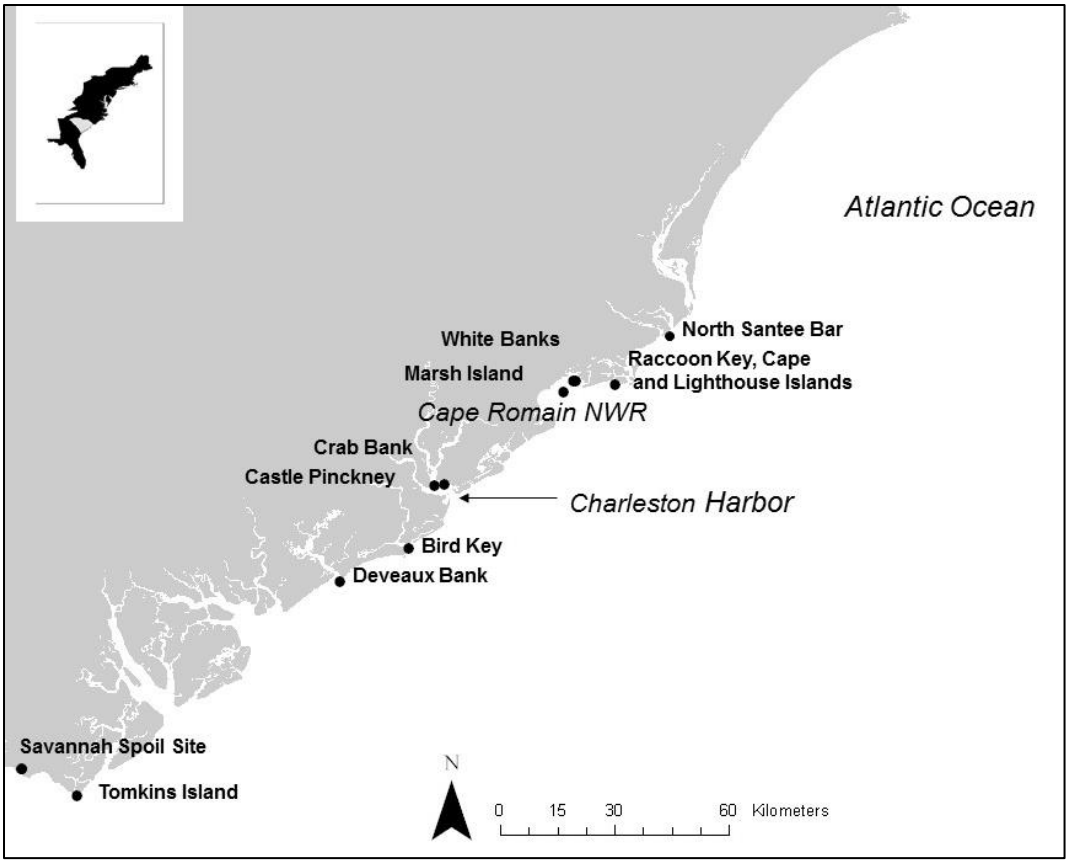

Figure 10. Locations of large seabird colonies in South Carolina from 2008 - 2016. Seabirds nested in other locations but the majority of nests were located at these sites.

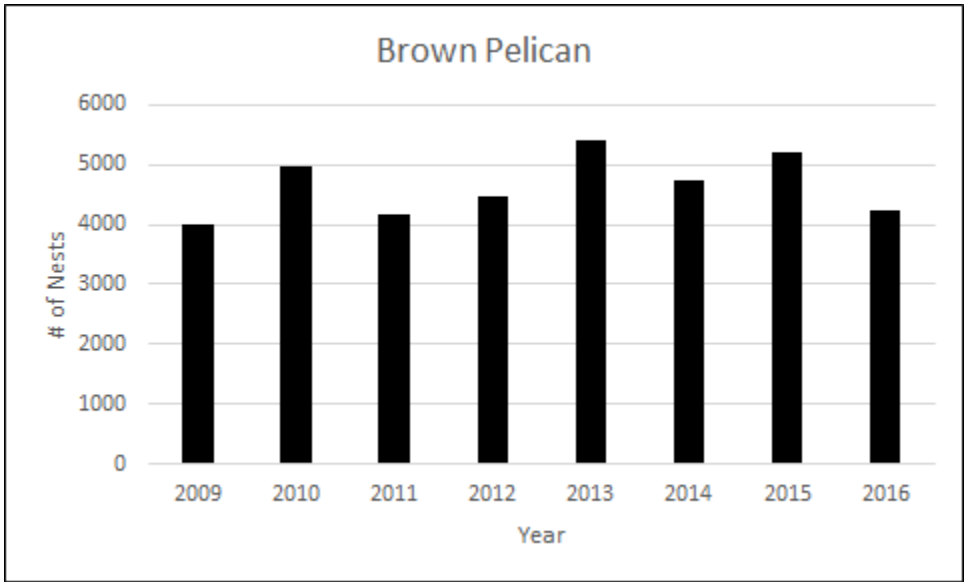

Figure 11. The number of brown pelican nests in South Carolina from 2009 to 2016.

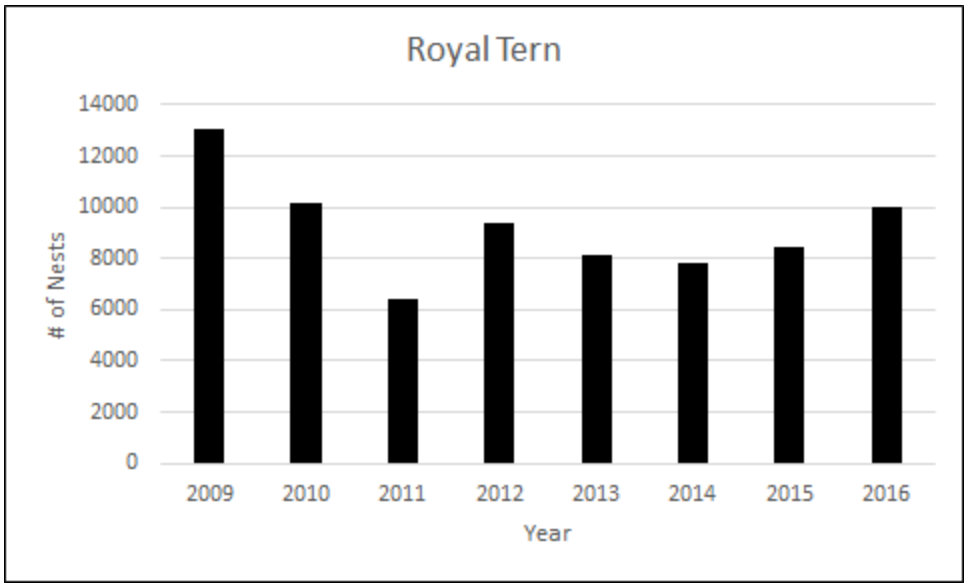

Figure 12. The number of royal tern nests in South Carolina from 2009 to 2016.

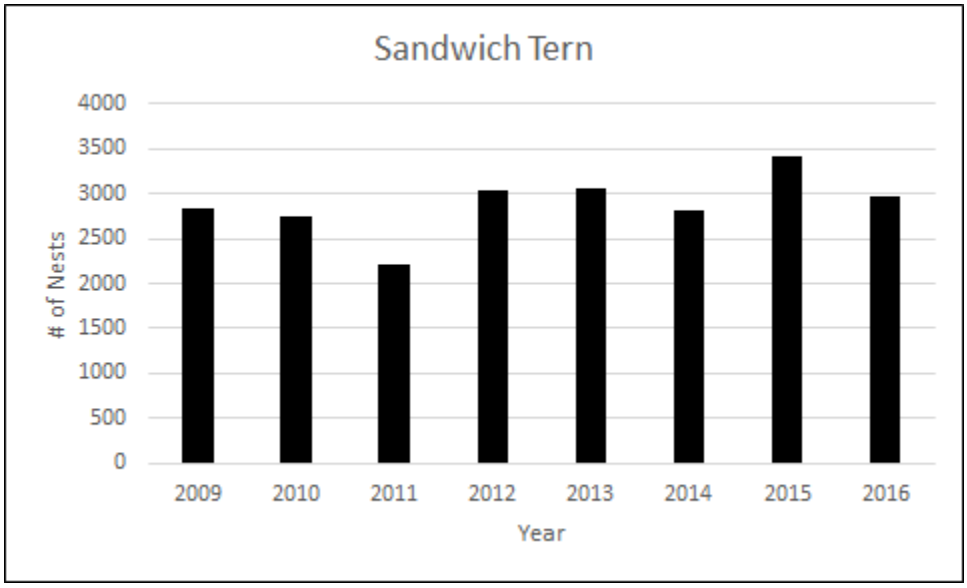

Figure 13. The number of sandwich terns nests in South Carolina from 2009 to 2016.

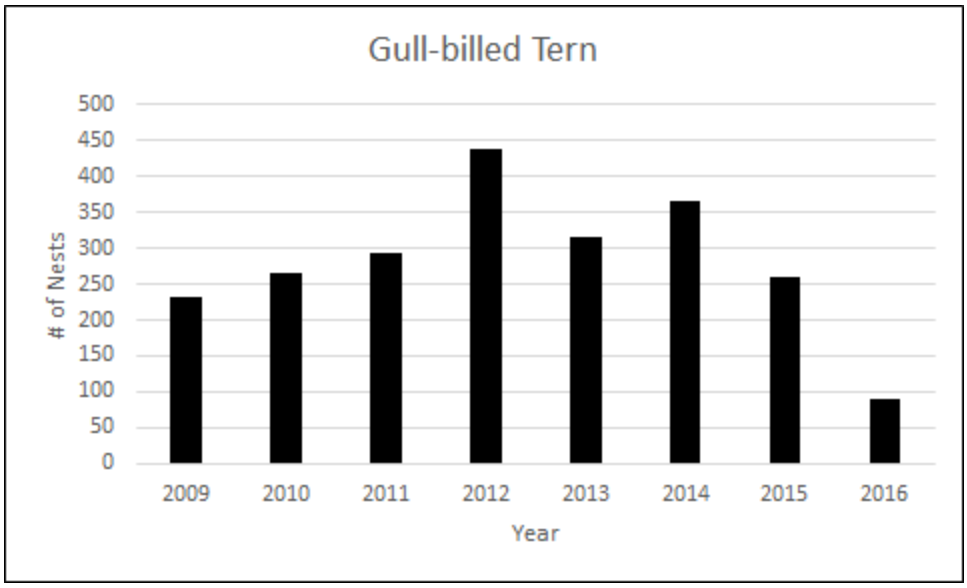

Figure 14. The number of gull-billed tern nests in South Carolina from 2009 to 2016.

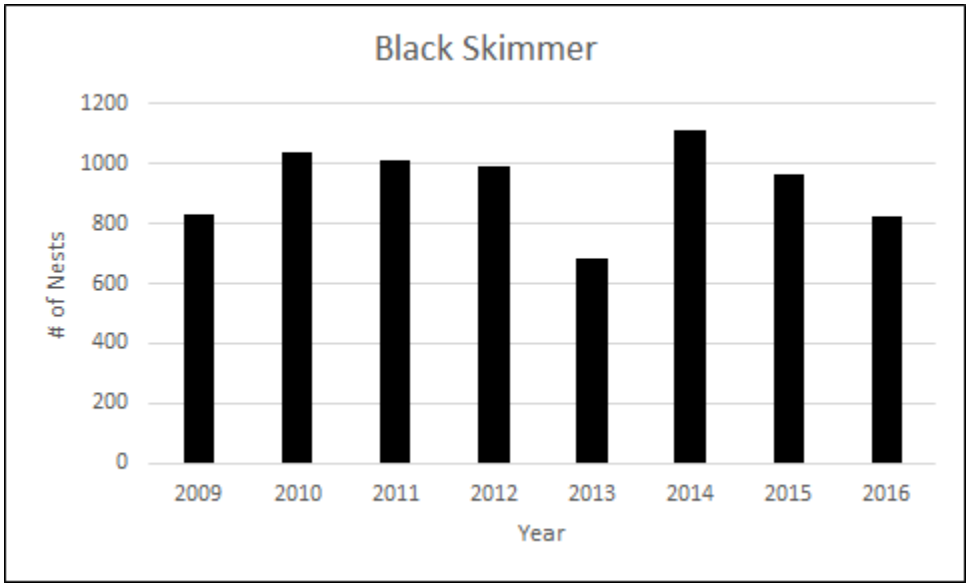

Figure 15. The number of black skimmer nests in South Carolina from 2009 to 2016.

Ground Nesting Least Terns

Least terns (*Sternula antillarum*) nest in large open areas of beach with little vegetation. In all Atlantic coast states the least tern is listed as either state endangered, threatened, or a species of special concern. In South Carolina the least tern is listed as state threatened and a species of highest priority in the 2015 State Wildlife Action Plan thus we report on this seabird species separately. Since 2008, 35 coastal sites supported nesting least terns on the ground. All of the sites are located on beaches except for 5 spoil islands adjacent to the Savannah River. These islands were built in 1995 by the Army Corps of Engineers as mitigation for deepening of the Savannah River and harbor. 5 (14%) beach sites were

accessible by a vehicle, and the remaining 30 (86%) sites which include barrier islands, shell rake islands, and ephemeral sand bar islands were only accessible by boat.

Since 2008 public properties including state and federally managed lands supported 84% of least tern nesting in South Carolina (Figure 16). Private beach properties supported 17% of least tern nesting. Over the 9 nesting seasons 4,944 nests were counted, with an average of 550 nests/year. Sites were visited every 7-10 days to assess colonies. Successful colonies were determined by the presence of fledges. The causes of failed colonies were identified.

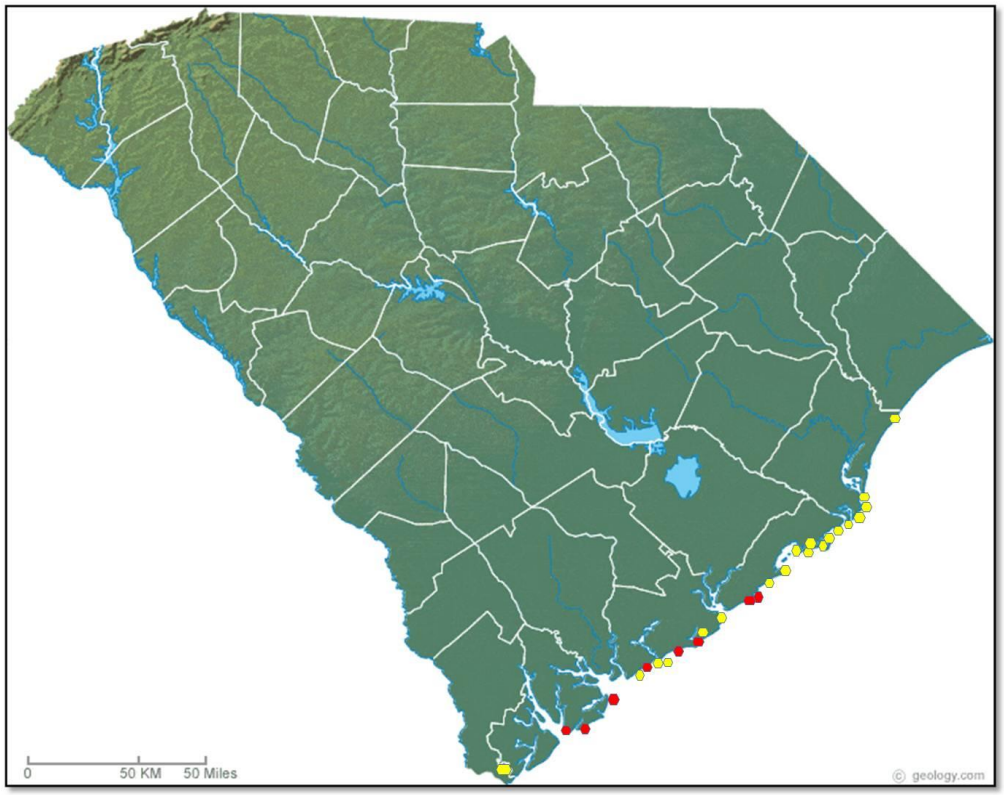

Figure 16. Least tern ground nesting sites on the South Carolina coast from 2008 through 2016. Publicly managed sites are in yellow; privately owned beach properties are in red.

Because of increased human disturbance on beaches, least terns now nest on pebbled roofs and other artificial sites. From 2008 to 2016 the total number of least tern nests in South Carolina was 10,249, mean 1139/year. 52% (5,305) were on flat gravel-covered roofs, and 48% (4,944) were on ground sites (Figure 17).

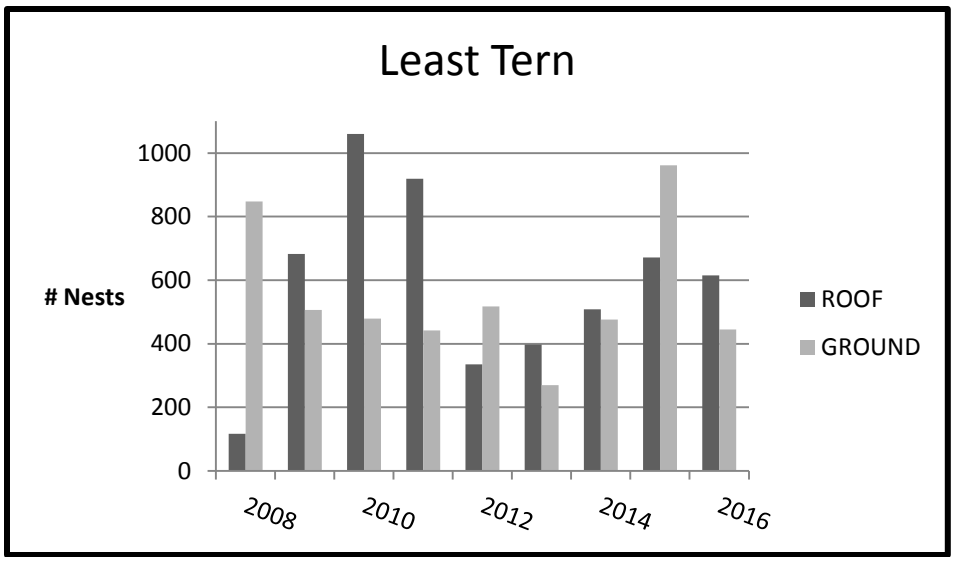

Figure 17. Number of least terns nesting in South Carolina by habitat type (on ground and on roof top).

Least Tern Roof (and artificial habitat) Nesting

All least tern roof nesting sites in South Carolina were found from Charleston to Myrtle Beach with 2 inland sites (Shaw Air Force Base and Camden High School) extending 90 to 100 miles from the coast (Figures 18 and 19). Initially management of roof nesting least terns was limited to identification of roof sites and nest censuses until 2013 when additional staff was able to devote increased time and effort to more comprehensive management. Manmade sites (N = 30), primarily pebbled roofs, were monitored for activity (Table 6).

Figure 18. Least tern nesting sites on pebbled roofs in Charleston and Berkeley Counties monitored during 2008 to 2016. Roof sites identified by red dots were active during the beginning of the monitoring period, but were no longer suitable for nesting by 2016. Inactivity at a site was caused by conversion of pebbled roofs to roofs with unsuitable roofing material or destruction of the building. Sites identified by yellow dots were still active in 2016.

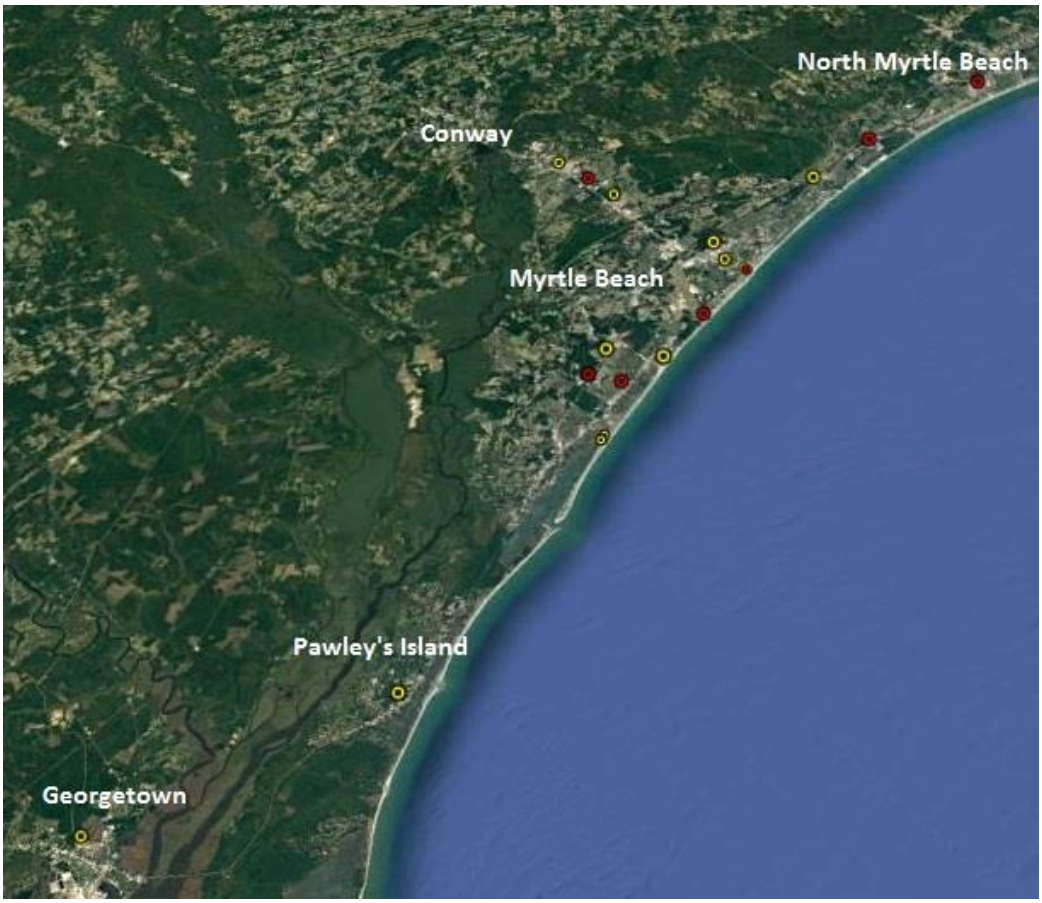

Figure 19. Least tern nesting sites on pebbled roofs in Georgetown and Horry Counties monitored during 2008 to 2016. Roof sites identified by red dots were active during the beginning of the monitoring period, but were no longer suitable for nesting by 2016. Inactivity at a site was caused by conversion of pebbled roofs to roofs with unsuitable roofing material or destruction of the building. Sites identified by yellow dots were still active in 2016.

Table 6. From 2008 through 2016 the number of known active least tern roof nesting sites and the number of nests. *In 2008 and 2012 all known roof nesting sites were not assessed for activity, thus during these years total nests are a minimum.

YEAR	KNOWN SITES	ACTIVE SITES	TOTAL NESTS
2008*	20	9	117
2009	17	14	682
2010	19	17	1060
2011	21	13	919
2012*	13	7	335
2013	24	13	398
2014	24	13	508
2015	19	12	671
2016	30	22	615

Much of the Florida Shorebird Alliance guidelines for managing least tern nesting roofs (http://www.flshorebirdalliance.org/resources/rooftop-resources.aspx) were adopted and modified for use in South Carolina. Currently management of least tern roof nesting consists of: identifying new sites, assessing historical sites for active nesting, nest censuses, developing relationships with roof owners and businesses through visits and correspondence, recruiting volunteers to assist in monitoring roofs, and adapting certain roofs for increased reproductive success by placing fencing on roof edges and providing shade. A pamphlet was developed to inform business owners, building managers, and the public about roof nesting least terns (Figure 20). Business owners and building managers of roof sites are issued a displayable sign which identifies them as a conservation partner with SCDNR (Figure 21). Roofs are visited the first week in May to determine use by least terns, and then nest censuses occur by the third and fourth weeks. Each roof is visited every 10 days after the initial nest census to follow progression of the colony and continue communication with business owners and managers concerning the least terns. For each colony, reproductive success or failure is determined. The cause is identified for failed colonies. Successful colonies are determined by the presence fledged young. Roofs that are suitable for edge fencing and shade structures are determined from the prior season, and adaptations are placed on the roof in January through March. Letters are sent to roof owners and managers in January prior to the nesting season to report on the nesting at the site and to encourage roof and HVAC maintenance activities be scheduled prior to May to avoid disturbance to nesting least terns.

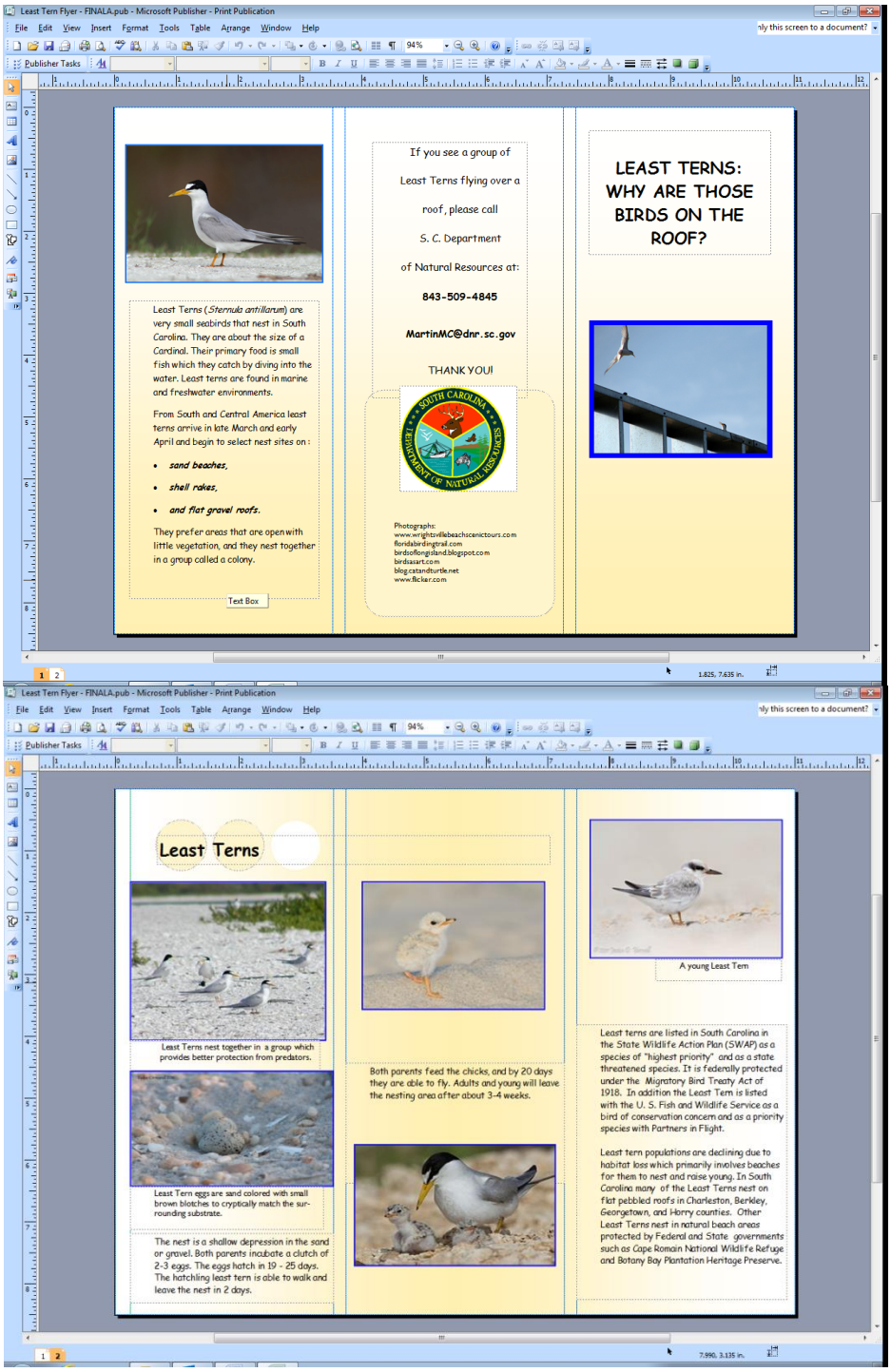

Figure 20. Roof nesting least tern informational pamphlet for business owners, building managers, and the public.

Figure 21. Displayable sign which identifies the managers of a building with nesting least terns on the roof, as a conservation partner with SCDNR.

Most of the flat gravel-covered roofs in SC are 20 years old. New building construction guidelines adopted in 2012 abolish the use of any gravel on roofs in hurricane prone regions. Newly constructed roofs use a membrane which is not suitable for least tern nesting. Since 2008, 22 roof nesting sites have been lost due to conversion of the roof to meet new construction standards or by complete razing of the building.

During this project 3 artificial habitats, other than rooftops, were monitored for least tern nesting activity. In 2011 least terns were observed nesting on the concrete supports beneath the Ravenel Bridge across the Cooper River between Charleston and Mt Pleasant. The sites are flat areas 7 ft. wide by 13 ft. long which were covered in broken clam shells. In 2014, 24 least tern nests were laid on 3 sites of the same size as above and

on one site twice as large, but all of the chicks fell to the water before maturing to flight. The South Carolina Department of Transportation was unable allow SCDNR to place fences around the nesting sites, thus areas were swept clean of shell to prevent nesting by the least terns. No nesting occurred in 2015, but least terns used a support near the middle of the bridge in 2016. This site will be swept clean of shell prior to the 2017 nesting season.

Another site which was discovered in 2016 is located at the British Petroleum Cooper River Chemical Plant. Least terns have come to the site for over 20 years and nested in a gravel covered area adjacent to ponds used to clean the effluent produced in the chemical production process. The average number of adults at the site since 2005 is 64. No nest censuses were done, and reproductive success is unknown. Management plans are in process to increase nesting substrate, erect fencing to control predator and human access, and provide shade and fresh water.

The third site is located on Pier Romeo adjacent to the NOAA Office for Coastal Management in Charleston. The pier is a concrete structure 600 ft. long extending over the Cooper River, and it is no longer in use for docking ships. In partnership with NOAA and USFWS Ecological Services, pea gravel was placed at the end of the pier in a 120 ft. by 30 ft. area. A Murremaid Sound System played least tern colony calls, and least tern decoys and shade in the form of wooden pallets were placed. In June, 5 pairs of least terns that likely failed their first nesting attempt in another area came to the pier. By mid-August, 7 young were observed to have fledged. Plans are to continue management at this site with hopes of increasing the colony to 30 - 40 pairs.

c. Monitor shorebird populations (resident and migratory species).

Red knot

The red knot (*Calidris canutus*) is a large sandpiper that breeds in the high Arctic. The *rufa* subspecies consists of two populations: long and short distance migrants. The majority of the *rufa* subspecies is made up of long distance migrants that spend the winter in the southern part of South America including Brazil and Tierra del Fuego. A smaller portion of the subspecies consists of short distance migrants that spend the winter in the southeastern part of the United States including South Carolina, Georgia and Florida. The number of red knots has declined nearly 85% over the last 15 years from an estimated population of over 150,000 to the current number of approximately 25,000 (Dey *et al*. 2011). Because of this drastic population decline, the red knot is listed as a Threatened Species under the Endangered Species Act. Reasons for this decline may be influenced by food availability especially during migration. Red knots forage on horseshoe crab eggs in the spring during their northbound migration. Declines in horseshoe crab spawning, especially in the Delaware Bay, a traditional stopover site, is believed to be a major cause of the reduction of the red knot population. Horseshoe crabs also spawn on South Carolina's beaches, and recent surveys suggest that South Carolina may also contribute as a stopover site during migration.

To understand how South Carolina's resources contribute to these shorebirds, we banded and conducted re-sight surveys to document the status of red knots in South Carolina. Flocks of red knots were captured using cannon nets and fitted with a U.S. Geological Survey metal leg bands and unique field readable engraved flags. Captured birds were measured, weighed and, when appropriate, aged by plumage. During re-sight surveys, spotting scopes were used to visually scan flocks for flagged knots and alpha-numeric flag codes were recorded. A database of banded birds observed in South Carolina was created and all data were also submitted to bandedbirds.org.

During capture, many red knots were fitted with light sensitive geolocators (British Antarctic Survey) following methods outlined in Niles *et al*. 2010. Geolocators record global position and are lightweight enough for red knots to carry during their vast migration. Geolocators must be recovered to obtain the recorded data, therefore birds must be recaptured to remove the devices.

Over 700 red knots have been banded in South Carolina from 2010 -2016 and 121 geolocators have been deployed (Table 7). Currently 11 geolocators have been recovered and efforts to recapture birds with these devices will continue in the future.

Table 7. Dates, locations, and numbers of red knots banded in South Carolina during 2011-2016. Table includes number of birds banded, re-captured, number of geolocators removed, and number of geolocators deployed on red knots at each location.

Date	**Location**	**Originally Banded**	**Re-captures**	**Geolocators Recovered**	**Geolocators Deployed**
7 May 2010	Bird Key	54	5	0	0
23 March 2011	Kiawah Island	108	52	3	9
18 October 2011	Harbor Island	137	2	1	25
12 April 2012	Deveaux Bank	195	20	1	30
1 April 2014	Kiawah Island	35	28	4	0
21 April 2015	Bird Key	122	23	2	20
16 October 2015	Marsh Island	2	0	0	2
8 May 2016	Deveaux Bank	13	1	0	11
9 May 2016	Deveaux Bank	5	0	0	5
10 May 2016	Deveaux Bank	32	0	0	21
Total		**703**	**131**	**11**	**123**

Data from geolocators are currently being analyzed by outside parties using software provided by the British Antarctic Survey. The data from geolocators that have been recovered illustrate individual red knot migration paths as well as wintering and breeding locations.

References

Dey, A. D., et al. "Update to the status of the Red Knot Calidris canutus in the Western Hemisphere, April 2011. Draft update to Status of the Red Knot (Calidris canutus rufa) in the Western Hemisphere." *Studies in Avian Biology* 36 (2011).

Niles, L.J., Burger, J., Porter, R.R., Dey, A.D., Minton, C.D.T., Gonzalez, P.M., Baker, A.J., Fox, J.W. & Gordon, C. 2010. First results using light level geolocators to track Red Knots in the Western Hemisphere show rapid and long intercontinental flights and new details of migration pathways. *Wader Study Group Bull.* 117(2): 123–130.

Statewide winter shorebird surveys

During the winters of 2014 and 2015, we organized the first statewide winter shorebird surveys conducted in South Carolina. The majority of the shorebirds were counted by SCDNR staff. In 2014, although the weather was not ideal, 38,235 shorebirds and 28 species were counted from Jan 31- Feb 7. In 2015 many people surveyed on windy days but the weather was much improved from the previous year's conditions. 47,287 shorebirds, 28 species/shorebird categories were counted Jan 22 to Jan 31, 2015. In 2014, 123 participants surveyed 54 sites and in 2015 there were 122 participant days, 57 sites surveyed, 149 miles of habitat surveyed and 175 hours logged.

In 2014, because bad weather hindered boating, a few beaches that have numerous shorebirds were not surveyed. They are highlighted in blue (Table 8). The Cape Romain Region (Cape Romain NWR to Dewees) had 16,031 (42%) shorebirds. Limited impoundments were surveyed this year. Although the ones surveyed are probably the best ones in the state because they are not completely flooded for waterfowl management. Sites with impoundments (Cat Is., Bulls Is. and Savannah Spoil Sites) had 5911 (16%) shorebirds. Only one shell rake boating route was covered. The ICW in Cape Romain Region (from McClellanville to Dewees) had 7759 (20%).

Better conditions in 2015 allowed more areas to be covered (Table 9). Dunlin (27,087) were over half the total shorebirds. Morris Island (south end) and Bird Key were surveyed but had no shorebirds. These 2 sites often have hundreds of shorebirds but conditions were very windy on survey days and we expect the birds were somewhere else, out of the wind. Similar to the 2014 survey, the high count was on the ICW (Intracoastal Waterway) shell rakes in The Cape Romain Region (Cape Romain NWR to Dewees) which had 8895 (19% of total) shorebirds. Kiawah (east end) had the high count for a beach with 5177 shorebirds. South Carolina has miles of shell rakes that were not covered in these surveys, thus they are a minimum count of shorebirds that use South Carolina coastal areas.

Table 8a, 8b. Results from a statewide survey north to south for all shorebirds conducted Jan 31- Feb 7, 2014 Table 8a - north of Charleston Harbor, Table 8b - south of Charleston Harbor and statewide totals. 38,235 shorebirds and 28 species were counted. Because bad weather hindered boating, a few beaches that probably have numerous shorebirds were not surveyed. They are highlighted in blue. Additionally, extreme high tides pushed shorebirds off some traditional sites thus this is a minimum estimate of shorebirds on South Carolina coast during the survey window.

	Waites Island North End/Jetty/Little River Inlet	Myrtle Beach State Park	Garden City Beach	Garden City	Litchfield	Pawley's Is	Huntington Beach SP--Mullet Pond	North Inlet, Debidue Beach	North Inlet, Bosum's Pt	North Inlet, Goat Island/Clambank	North Inlet, North Is	North Island, south end	Cat Island	South Island Beach	South Island Impoudments	Sand Island	Cedar Island	Murphy Island	AICW, Cape Romain Region	Cape Romain NWR, Cape Island	Cape Romain NWR, Deepwater Point	Cape Romain NWR, Lighthouse Island	Cape Romain NWR, Raccoon Key	Cape Romain NWR, White Banks	Cape Romain NWR, Marsh Island	Cape Romain NWR, SW Bull's Bay Shellrakes	Cape Romain NWR, Bulls Island N end	Cape Romain NWR, Bulls Island S end, impoudments	Capers Island	Dewees Island	Isle of Palms, NE Beach	Isle of Palms, Breach Inlet	Sullivan's Is, Breach Inlet	Sullivan's Is, Station 28 Beach	Sullivan's Island Station 16	Fort Moultrie National Monument	Pitt Street Causeway
American Avocet													31		369	14																					
American Oystercatcher									65		25			8		5			1184	40	23	182	41	171	175	14	2	9	30									45
Black-bellied Plover	1		2			4		1		1	19		5	18	79	15	2		121	66		34	106	1	4	2	7	24	15	4				4				2
Black-necked Stilt																																						
Dunlin	268		33			160	20			40	1994		265	59	568	162			2890	1082	1	891	1317	9	40	12	9	864	550	376	110			40				35
Greater Yellowlegs							1				1		9		56	9												66	10	2	1							
Killdeer		2								18			4										2		2		2	43	1	5	14		11	3		5		
Least Sandpiper										2			16	14	36	11				2			35		6				3						6		
Lesser Yellowlegs							1						18		101													1									
Long-billed Curlew																							2														
Long-billed Dowitcher													43		4																						
Marbled Godwit															1	2			723						1		1										
Peep species													43	12	72	41																					
Piping Plover			1											1		3						2			1			2	1					5			
Purple Sandpiper																																		50			
Red Knot			3					1			1			6		14				6			5							50			80			
Ruddy Turnstone			40	7	8	4		2			9			9	1	12			48	16	13	8	27	110	65	17	13	2	3	2	3			100			
Sanderling	8	5	22	2	4	5		12			10			19		36	1	1		31		48	10	3	13		19	7	30		14			102			
Semipalmated Plover			2			75							16	19	288	212			14	37		64	208		7			12	60	28	5			1	1		2
Short-billed Dowitcher	86						1	120		15	543		15	39	329	23			2401	128	12	149	2				22	50	45	55						110
Short-billed/Long-billed Dowitcher													68	21	170	95																				
Spotted Sandpiper																												1								
Stilt Sandpiper																																				
Western Sandpiper	23		5				1						14	22	72	26			12	50		9	269					8	15	50						
Whimbrel															1	1						2	1													
Willet	1	1	1		1	1		1		7	1		3	14	9	42	1		366	30	24	48	10	40		1	4	1	25	3	3	10	1	11			5
Wilson's Plover																													1							
Wilson's Snipe													7		3													11		1						
Total	387	8	109	9	13	249	24	137	65	83	2603		557	261	2159	723	4	1	7759	1488	73	1437	2035	334	314	46	79	1101	789	576	150	10	12	396	7	5	199

	Morris Island, north end	Clark Sound-Folly Rd	Morris Island, South end	Folly, north end	Folly, south end	Bird Key	Kiawah, East Beach	Kiawah, West Sand Spit	Seabrook Island	Deveaux Bank	Botany Bay Island	Botany Bay, Townsend end	Interlude Beach	Edisto Island, Edingsville Beach	Edisto Beach State Park	Edisto Beach	Pine Island	Otter Island	Harbor Island	Hunting Island SP	Fripp Is	Pritchards Island	Capers Island	Dafuskie Island	Bay Point	Savannah Spoil Site	Wright River Marsh adjacent to 14B	US 17 pond, Hardeeville	Tomkins Island	Total
American Avocet																										199				199
American Oystercatcher						2				26		5		4	3	1		1												42
Black-bellied Plover		25	7	1		12	11	48	1	97	2	3	2	12	10	11		31	6	2	5					28	423			737
Black-necked Stilt																										1				1
Dunlin	30	160	350	470		508	822	410	11	792		89	13	259		334		424	184	43	398					1910	2189			9396
Greater Yellowlegs							14			4					5			2								20	12			57
Killdeer	5	2	3	2			7		3	3		1			1			1		4	13			4		152	10	1		212
Least Sandpiper		5	1				1	2		3				3	1											589	34			639
Lesser Yellowlegs																					1					8	4	202		215
Long-billed Curlew																														0
Long-billed Dowitcher																										198	1			199
Marbled Godwit							1		1	19				3		2		8			1									35
Peep species																														0
Piping Plover					1		3		2	10									3		4									23
Purple Sandpiper																4													2	6
Red Knot					25	1	153	12	140	3		1		6	2				1	36										380
Ruddy Turnstone	3	3	10	4		13	11	12	2	27		13		32	3	30		19	7	15	5					1			240	450
Sanderling			40	16	10	19	210	8	6	73				9	11	15		13	90	64	22			3					148	757
Semipalmated Plover		160	4	30	300	40	347	12	3	403						35		106	75	35	245					169	397			2361
Short-billed Dowitcher		18				51	221			96					1	110		17												514
Short-billed/Long-billed Dowitcher																										453	50			503
Spotted Sandpiper		1																												1
Stilt Sandpiper																										19	15			34
Western Sandpiper		55				12	82			259								30	8							504	265			1215
Whimbrel		1													1															2
Willet		35	3		1		4		4	66	1	2	2	34	4	27		15	2	17	5			5			19			246
Wilson's Plover							1					1			1			6												9
Wilson's Snipe							6																			2				8
Total	38	465	418	523	337	658	1894	504	173	1881	3	115	17	362	43	569		673	376	216	699			12	0	4253	3419	203	390	18241

Table 9a, 9b. Results from a statewide survey north to south for all shorebirds Jan 22 to Jan 31, 2015. Table 9a - north of Charleston Harbor; Table 9b - south of Charleston Harbor and statewide totals.

	Waites Island North End/Jetty/Little River Inlet	Waites Island Beachfront	Cherry Grove/Hog Inlet	Myrtle Beach State Park	Garden City Beach	Huntington Beach SP	Litchfield/Pawleys	North Inlet	North Island, south end	South Island Beach	South Island	Cat Island	Sand Island	Cedar Island	Murphy Island	AICW - Marker 64 to Marker 115	Cape Romain NWR, Cape Island	Cape Romain NWR, Deepwater Point	Cape Romain NWR, Lighthouse Island	Cape Romain NWR, Raccoon Key	Cape Romain NWR, White Banks	Cape Romain NWR, Marsh Island	Cape Romain NWR, SW Bulls Bay shellrakes	Cape Romain NWR, Bulls Island N end	Cape Romain NWR, Bulls Island S end, impoundments	Capers Island	Dewees Island	Isle of Palms, NE Beach	Isle of Palms, County Park	Isle of Palms/Sullivans Is. Breach Inlet	Sullivan's Is, 332 Izlar St	Sullivan's Island Station 16	Pitt Street Causeway
American Avocet											190	69																					
American Oystercatcher	1		3					94	1	2			2	2	4	1103	22	21	40	56	170	78	14	2	16	15					24		
Black-bellied Plover		1	3			45	2	21		18	59	6	27		2	190	68		28	35	2	1		11	1	30	34						3
Dunlin			4		225	26	1	1715		192	411	72	84		720	5734	2303		368	517	56	35		84	1226	300	1440			71	250		24
Greater Yellowlegs			6					22		4	71	50						2							4	2	31						
Killdeer								1																			3						
Least Sandpiper			3								25		2		2		4		2	103		9					2						
Lesser Yellowlegs											29	48														5	2			3			
Long-billed Curlew																			2														
Long-billed Dowitcher											35	12														5							
Marbled Godwit																323			6														
peep sp.											38	5																					
Piping Plover						0		1					3		8				8			1			6	3							
Purple Sandpiper	6																																
Red Knot	2					46		4		61			11		6					20				2									
Red Phalarope								1																									
Ruddy Turnstone	51		1			32		11		13			34		4	11	3	3	26	40	51	81	10	12	21	10							
Sanderling		22	4	2	4	23	10	20		26			63	3	15		14		36	55	6	26		131	139	50	27	4		9		10	
Semipalmated Plover			23		20	5		62		27	140	3	68	4	155	65			87	499	15	19	1		800	25	437				50		1
Short-billed Dowitcher			426		90	6		90		87	106	35	51			828	73	3	114	8				3	500	50	275				3		2
Short-billed / Long-billed Dowitcher											378	87																					
Spotted Sandpiper								1																	1		1						
Western Sandpiper					45			27			58		15		130	146	6		17	96					43	20	52						2
Whimbrel																			1							20							
Willet	2	2	12	1	1	13	2	68		9	21	9	15			495	24	30	52	35		3	4		5	20	20		6		20		
Willet (Western)																																	3
Wilson's Plover													1		4					1					1								
Wilson's Snipe												5																					
Grand Total	62	25	485	3	385	196	15	2138	1	439	1561	401	376	9	1050	8895	2517	59	787	1465	300	253	29	245	2763	555	2324	4	6	80	350	10	35

	Morris Island, south end	James Is, docks	Clark Sound-Folly Rd	Folly, north end	Folly River Docks	Folly Beach County Park	Bird Key	Kiawah, East Beach	Kiawah, West Sand Spit	Seabrook Island	Deveaux Bank	Botany Bay Island	Botany Bay, Townsend end	Interlude Beach	Edisto Island, Edingsville Beach	Harbor Island	Hunting Island SP	Fripp Island	Pritchards Island	Little Capers Island, north end	MCRD Parris Island	Hilton Head Is	Daufuskie	Turtle Island	Tomkins Island	Grand Total
American Avocet																										259
American Oystercatcher		223			228						12	2	2	3	2										11	2153
Black-bellied Plover		34			110	1		2	7	1	77	2	2		19	7	1	6	16	1	15	7			1	896
Dunlin		1045	3	47	670			3448	842	407	754	16	33	10	191	100		668	2086	14	500	375		2	18	27087
Greater Yellowlegs								1			2									18						213
Killdeer																										4
Least Sandpiper								5	6		7				4			2		5	70					251
Lesser Yellowlegs																										87
Long-billed Curlew																										2
Long-billed Dowitcher																										52
Marbled Godwit											33				1							100		22		485
peep sp.						10		25																		78
Piping Plover						4		2	1	1	14					18		6				4				80
Purple Sandpiper																									6	12
Red Knot									7		89				1				270							519
Red Phalarope																										1
Ruddy Turnstone		3		9				1	8	2	45	3	7	3	21	10	6	7	2		20	18		36	700	1315
Sanderling				66				70	64	29	78	14			15	7	26	42	1			48	6	27	228	1420
Semipalmated Plover				210	1			1502	94	14	468					340		80	102		250	1				5568
Short-billed Dowitcher			1								91								22		150	60				3074
Short-billed / Long-billed Dowitcher		343			495																					1303
Spotted Sandpiper																							1			4
Western Sandpiper		75	1			5		116	18	43	190					2		4	12		100	2				1225
Whimbrel																										21
Willet		27	16	2	23	1			1	1	29	5	3	2	13	2	6	1	43		60	8	11	34		1157
Willet (Western)																										3
Wilson's Plover								5			1															13
Wilson's Snipe																										5
Grand Total	0	1750	21	334	1527	21	0	5177	1048	498	1890	42	47	18	267	486	39	816	2554	38	1165	623	18	121	964	47287

Wilson's plover

Wilson's plovers, nest on beaches and occasionally on shell rakes in South Carolina. Although they are not federally listed, The U.S. Shorebird Conservation Plan identified Wilson's Plover as a "species of high concern" are listed as state threatened in South Carolina.

The purpose of this study was to determine the abundance and distribution of nesting pairs of Wilson's Plovers in South Carolina. For the first time, all suitable nesting habitat on the beaches of South Carolina was surveyed for breeding Wilson's Plovers. This study provides baseline data for South Carolina that can be used to analyze population trends and to identify important sites for conservation. Surveys were conducted in 2009 (May 10 – July 15), 2010 (April 20 – June 7), 2011 (April 19 – June 1) and 2012 (March 29 – May 24). All suitable nesting habitat on beaches was surveyed for pairs of Wilson's Plovers at least once during the study, except 4km of coast at Edingsville Beach. Beaches with sea walls and rocks or with forest or thick vegetation adjacent to the high tide line were not surveyed because plovers prefer nesting in more open areas with sparse vegetation. Sites with heavy human disturbance, such as Myrtle Beach, were considered unsuitable habitat and were also not surveyed. Thirty six individuals, mostly volunteers, participated in the surveys but the majority of the sites were surveyed by four individuals.

A mean of 376 pairs were recorded and 131km of suitable coastline habitat were surveyed (Table 10). The total number of adult plovers counted during the four years (634) included 27 plovers that observers were uncertain of their age and breeding status. Nests with eggs were observed from April 19 to June 3. Thorough nests searches were not conducted during the study, so these dates represent a minimum window of nesting in South Carolina. Fledglings were recorded from May 10 to July 15, which is the latest date surveys were conducted, thus these dates also represent a minimum window fledglings are present.

Table 10. Number of estimated Wilson's Plover pairs followed by (total number of plovers counted) during the breeding season at 41 sites, listed north to south, in South Carolina. Total number of plovers includes adults and plovers of unknown age. Mean number of pairs (followed by standard deviation) for each site. Each site was visited at least once during 2009-2012. Blank spaces indicate the site was not surveyed. From: Sanders, F. J, Martin, M. C., Spinks, M. D., Wallover, N. J. 2012. Abundance and distribution of Wilson's Plovers during the breeding season in South Carolina. The Chat 76: 117 -124.

Sites	Pairs (total birds)				Mean pairs (SD)
	2009	2010	2011	2012	
Waites Island	7 (11)	8 (12)			8 (1)
Huntington Beach	3 (5)	5 (12)			4 (2)
Litchfield Beach	2 (5)	2 (2)			2 (0)
Pawley's Island		0			0
Debideaux	3 (3)	0			2 (2)
Bosun's Point	1 (1)				1
North Island	26 (62)	23 (41)			25 (2)
Sand Island		9 (17)			9
South Island, Gibson Pond	2 (9)				2
South Island			15 (26)		15
Cedar Island	16 (29)	14 (25)			15 (1)
Murphy Island	8 (15)				8
Cape Island	29 (58)				29
White Banks		2 (4)			2
Raccoon Key	15 (26)	16 (30)			16 (1)
Lighthouse Island	17 (35)	23 (45)			20 (4)
Bulls Bay shell rakes		9 (18)			9
Bull Island	8 (14)	10 (16)			9 (1)
Capers Island	8 (14)	6 (11)			7 (1)
Dewees Island	5 (9)	4 (8)			5 (1)
Isle of Palms	0 (0)				0
Sullivan's Island	2 (3)				2
Morris Island, North end	2 (3)	1 (2)			2 (1)
Morris Island, South End			33 (66)		33
Folly Beach	11 (22)	7 (17)			9 (1)
Bird Key	12 (22)	8 (16)	7		9 (3)
Kiawah Island	28 (53)	26 (65)			27 (1)
Seabrook Island		2 (4)			2
Deveaux Bank	1 (3)				1
Botany Bay Plantation	7 (12)	12 (21)			10 (4)
Edisto Beach State Park		4 (7)			4
Otter Island	3 (6)	3 (6)		6 (16)	4 (2)
Harbor Island	2 (4)	5 (10)	14 (27)		7 (6)
Hunting Island	1 (2)				1
Fripp Island	3 (5)		0 (0)		3 (2)
Pritchard's Island		1 (2)	0 (0)		1 (1)
Little Capers			37 (73)		37
St Philips	2 (5)	1 (2)		1 (2)	1 (0)
Bay Point				11 (20)	11
Savannah Spoil Sites	43	24	18		28 (13)
Total					376

International Shorebird Surveys

To help understand shorebird populations, SCDNR participated in and helped organized International Shorebird Surveys (ISS), a program run by Manomet Center for Conservation Sciences. These surveys were developed to collect information on shorebirds during migration. Surveys also aid in identifying important staging areas, monitoring population trends, determining migration routes, and in the timing of different species migration. Surveys involve identifying and counting all shorebirds at a fixed location, or along a predetermined route. Surveys are conducted at least once a month. The gathered data is entered into the ISS Ebird Site. We organized workshops and data entry trainings to help surveyors identify sites and to participate in this international monitoring program. At the end of the 2016, 21 sites were active ISS sites (Figure 22, Table 11).

Table 11. Sites in South Carolina in 2016 where International Shorebird Surveys are being conducted. There are 2 sites on Bulls Island in Cape Romain National Wildlife Refuge.

SITE
Botany Bay
Cape Island
Cat Island
CRNWR Bulls Island (2)
Deepwater Pt
Deveaux Bank
Dewees
Fish Haul Creek, Hilton Head
Harbor Island
ICW Cape Romain Region
Interlude
Lighthouse Island
Marsh Island
Otter Island
Pine Island
Pitt Street Bridge
Raccoon Key
South Island
Sullivan's Island
SW Bulls Bay Shell Rakes

Figure 22. Locations of International Shorebird Surveys in South Carolina during 2008-2016. Sites in red have historical use (prior to 2006) but are no longer active and are targeted for reinitiating.

d. Develop an outreach/educational component of the seabird/shorebird project.

During this grant a SCDNR coastal birds webpage was developed (Figure 23). The webpage contains background information on seabird and shorebird ecology of South Carolina as well as what SCDNR does for these species such as management, research and conservation projects. Resource materials, brochures, and publications are also available on the webpage. The webpage will serve as a resource for the public to learn about South Carolina's coastal birds and SCDNR's efforts to protect them.

Figure 23. Screen shot from the South Carolina Department of Natural Resources web page about shorebird and seabird conservation.
http://www.dnr.sc.gov/wildlife/species/coastalbirds/index.html

Some key workshops during this grant period are listed below.

- Cohosted with Manomet 2 workshops to educate land managers about shorebirds and habitat management, especially in impoundments. One workshop was held at Yawkey Center and the other was a week-long workshop held on Bulls Island in Cape Romain NWR.

- Partnered with private and public biologists and managers to conduct a workshop: "Value Added Wetland Management: Ducks and More" held at Nemours Plantation. More than 80 participants from private and public lands learned about managing wetlands for not only waterfowl but shorebirds, specifically during spring migration. National shorebird coordinator opened workshop summarizing flyway and global significance of habitat in South Carolina.

- Conducted a workshop at DNR facility at Fort Johnson to solicit volunteers to conduct international shorebird surveys (ISS). Representatives from USFWS and Manomet lead instructions on survey protocol and data entry. Participants were from South Carolina and Georgia.

- Seabird and shorebird workshop held at DNR facility at Fort Johnson for anyone interested in learning more about these coastal species. Workshop covered wintering and nesting natural history, conservation and management.

- "Raising Awareness of Shorebirds" held at Harbor Island. This workshop covered wintering and nesting species and included a field trip to view migrating shorebirds feeding on horseshoe crab eggs. The workshop was taught by USFWS and SCDNR staff.

e. Apply pesticides where necessary to control avian ticks.
Avian ticks, *Carios capensis*, can be present in brown pelican nests (and other marine birds' nests). This ectoparasite can cause abandonment of nests and desertion of young. SCDNR checks for the presence of these soft bodied ticks by examining nest material of pelican nests at all colonies. If high levels of ticks are seen, an insecticide is sprayed on the pelican nests. Approximately 175 ml of a 0.5% dilution of Rabon_50 WP insecticide is hand-sprayed directly onto the nest material during peak incubation of pelicans. Rabon is commonly used on poultry and is approved for direct application to birds and their physical environment.

We observed high levels of ticks only at Tomkins Island and sprayed Rabon at this site. This seabird sanctuary is manmade and is approximately 20 feet high, thus salt water does not cover the island, even at high tides or during tropical storms. Ticks can overwinter in the soil and may be eliminated with salt inundation and erosion. Without these natural forces, tick levels may continue to be a problem at Tomkins Island.

f. Partner in research, serve on graduate student committees and disseminate information in peer-reviewed journals.

Publications during this grant. These publications represent some of the research and surveying projects during this grant.

Murphy, S. P., T. Virzi, F. J. Sanders. 2017. Exploring Differences in Adult Survival and Site Fidelity of Migratory and Non-Migratory Populations of American Oystercatchers (*Haematopus palliatus*). Waterbirds, in press.

Collins, S. A., F. J. Sanders, P. G. R. Jodice. 2016. Assessing conservation tools for an at-risk shorebird: Feasibility of headstarting for American Oystercatchers *Haematopus palliatus*. Bird Conservation International, 26: 451-465.

Wallover, N. J., Martin, M-C. and Sanders, F. J. 2015. Monthly abundance and seasonal spatial distribution of shorebirds in Cape Romain National Wildlife Refuge, South Carolina. The Chat 79: 61-79.

Sanders, Felicia J., and Stacy J. Ray. "Encounters of Royal Terns (Thalasseus maximus) Banded in South Carolina." Southeastern Naturalist 14.1 (2015): 1-8.

Daphne Carlson-Bremer, Terry M. Norton, Felicia J. Sanders, Brad Winn, Mark Spinks, Batsheva A. Glatt, Lisa Mazzaro, Patrick Jodice, Tai C. Chen, and Ellen S. Dierenfeld, 2014.Circulating Fat-Soluble Vitamin Concentrations and Nutrient Composition of Aquatic Prey Eaten by American Oystercatchers (*Haematopus palliatus palliatus*) in the Southeastern United States. Journal of Avian Medicine and Surgery 28: 216-224.

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Snipes, K.C. and F.J. Sanders. Black Skimmer (*Rynchops niger)* breeding trends in South Carolina. 2012. Southeastern Naturalist 11: 437-446.

Snipes, K.C. and F.J. Sanders. 2011. Recoveries of Black Skimmers (*Rynchops niger)* banded in South Carolina. The Chat 75: 81-87.

Carlson-Bremer, D., T. M. Norton, K. V. Gilardi, E. S. Dierenfeld, B. Winn, F. J. Sanders, C. Cray, M. Oliva, T. C. Chen, S. E. Gibbs, M. S. Sepulveda, and C. K. Johnson. 2010. Health assessment of American Oystercatchers (Haematopus Palliatus Palliatus) in Georgia and South Carolina. Journal of Wildlife Diseases 46:772-780.

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